CHAPTER 5

DRIVE LINES, DIFFERENTIALS, DRIVE AXLES, AND POWER TRAIN ACCESSORIES

INTRODUCTION

Learning Objective: Identify the components and explain the functions and the maintenance procedures for a drive line assembly, differentials, drive axles, a transfer case, and a power takeoff unit. Describe the different types of universal and constant velocity joints. Explain the adjustments and measurements of the ring and pinion gears. Describe the procedures for removing and replacing axle bearings and seals.

One important function of the power train is to transmit the power of the engine to the wheels. In a simple situation, a set of gears or a chain could perform this task, but automotive vehicles usually are not designed for such simple operating conditions. They are designed to have great pulling power, move at different speeds, operate forward and reverse, and travel on rough as well as smooth surfaces. To meet these widely varying conditions, a number of units have been added. In this chapter we will discuss drive lines, differentials, drive axles (rear and front drive), and power train accessories (transfer cases and power takeoffs).

DRIVE LINE ASSEMBLY

Learning Objective: Identify the parts and the functions of different types of drive lines. Describe the different types of universal joints.

The drive line assembly has several important functions. It must perform the following:

- Send turning power from the transmission to the rear axle assembly.
- Flex and allow up-and-down movement of the rear axle assembly.
- Provide a sliding action to adjust for changes in drive line length.
- Provide a smooth power transfer.

The assembly provides a path through which power is transmitted from the transmission to the drive axle assemblies or auxiliary equipment. Vehicles, having a long wheelbase, are equipped with a drive shaft that extends from the transmission or transfer case to a center support bearing and a drive shaft that extends from the center support bearing to the rear axle.

The drive line assembly (fig. 5-1) consists of the following:

- SLIP YOKE—connects the transmission output shaft to the front universal joint.
- FRONT UNIVERSAL JOINT—the swivel connection that fastens the slip yoke to the drive shaft.
- DRIVE SHAFT—a hollow metal tube that transfers turning power from the front universal joint to the rear universal joint.
- REAR UNIVERSAL JOINT—a flex joint that connects the drive shaft to the differential yoke.
- REAR YOKE—holds the rear universal joint and transfers torque to the gears in the rear axle assembly.

SLIP YOKE (JOINT)

The type of transmission (manual or automatic) determines how the slip joint is connected to the drive shaft. On a manual transmission, the slip yoke is splined to the drive shaft with the yoke for the universal joint directly behind the transmission or transfer case, whereas, with the automatic transmission, the slip yoke is splined to the output shaft. Either way they serve the same purpose—to provide the necessary telescopic action for the drive shaft. As the axle housing moves forward and backward, the slip joint gives freedom of movement in a horizontal direction and yet is capable of transmitting rotary motion.

The slip yoke used with an automatic transmission has the outer diameter machined smooth. This smooth surface provides a bearing surface for the bushing and rear oil seal in the transmission. The transmission rear oil seal rides on the slip yoke and prevents fluid leakage out of the rear of the transmission. The seal also keeps dirt out of the transmission and off the slip yoke.

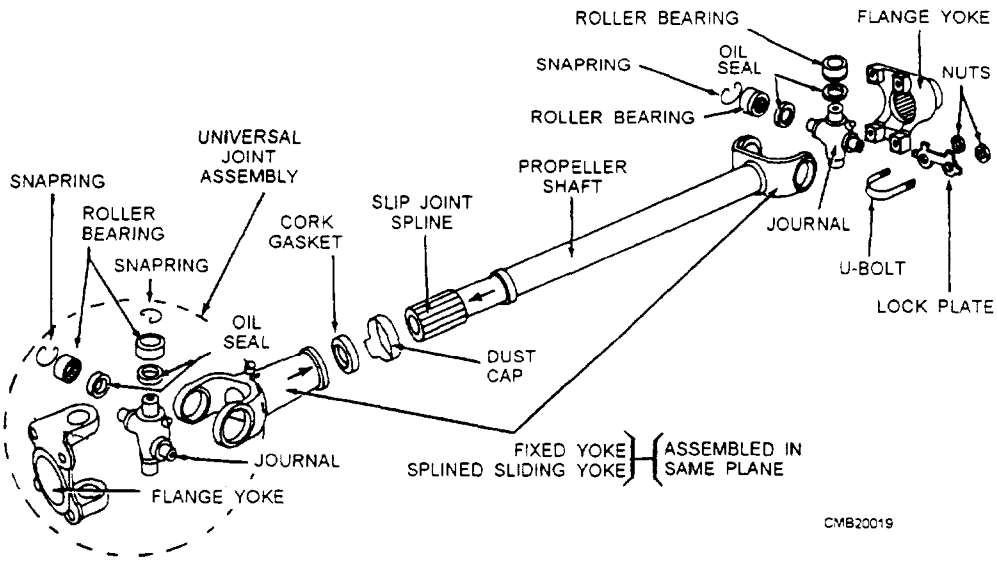


Figure 5-1.—Drive line assembly.

DRIVE SHAFTS

The drive shaft, also called a propeller shaft, is commonly a hollow steel tube with yoke(s) welded on the end. The tubular design makes the drive shaft strong and light. Most vehicles use a single, one-piece drive shaft. However, many trucks have a two-piece drive shaft. This cuts the length of each shaft to avoid drive line vibration.

Since a drive shaft spins at full engine t-pm in high gear, it must be straight and perfectly balanced (weight evenly distributed around center line of shaft). If NOT balanced, the shaft can vibrate violently. To prevent this vibration, drive shaft balancing weights are welded to the shaft at the factory. Small metal weights are attached to the light side to counteract the heavy side for smooth operation.

The drive shaft can be either open or enclosed, depending on the type of drive used. The HOTCHKISS drive has an open drive shaft that operates a rear axle assembly mounted on springs (fig. 5-2). The HOTCHKISS drive requires that the springs be rigid enough to withstand the twisting action (torque) of the rear axle and the driving and braking forces that the springs transmit to the frame. This type of drive is common to the equipment you will encounter in the Navy.

Another type of drive is a torque tube. Torque tubes differ from the Hotchkiss design in that a solid drive shaft is enclosed in a hollow torque tube and rotates within a support bearing to prevent whipping. One universal joint is used at the front of the drive shaft, and the rear of the drive shaft is attached to the axle drive pinion through a flexible coupler.

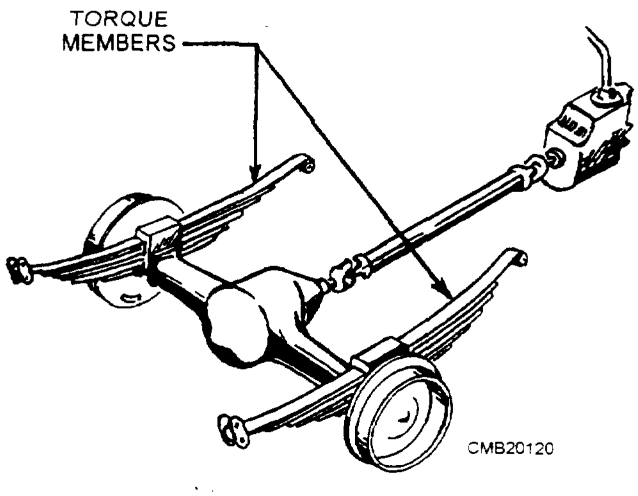


Figure 5-2.—Hotchkiss drive.

UNIVERSAL JOINTS

A universal joint, also called a U-joint, is a flexible coupling between two shafts that permits one shaft to drive another at an angle to it. The universal joint is flexible in a sense that it will permit power to be transmitted while the angle of the other shaft is continually varied.

A simple universal joint is composed of three fundamental units consisting of a journal (cross) and two yokes (fig. 5-3). The two yokes are set at right angles to each other and their open ends are connected by the journal. This construction permits each yoke to pivot on the axis of the journal and also permits the transmission of rotary motion from one yoke to the other. As a result, the universal joint can transmit power from the engine through the shaft to the rear axle, even though the engine is mounted in the frame at a higher level than the rear axle, which is constantly moving up and down in relation to the engine.

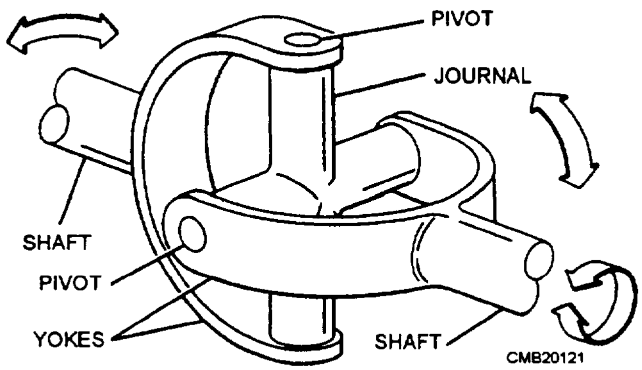


Figure 5-3.—Simple universal joint.

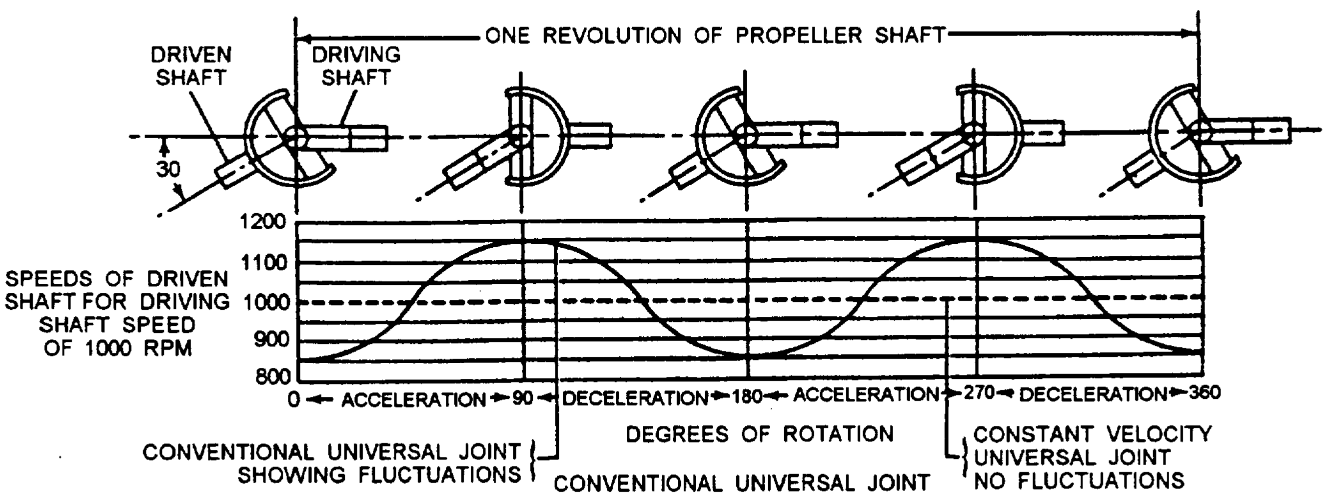
A peculiarity of the conventional universal joint is that it causes a driven shaft to rotate at a variable speed in respect to the driving shaft. There is a cyclic variation in the form of an acceleration and deceleration of speed (fig. 5-4). Two universal joints are placed in a drive shaft to eliminate the speed fluctuations of the shaft while the shaft is at an angle to the power source. The universal joints are placed at a 90-degree angle to each other and one counteracts the action of the other while in motion.

Three common types of automotive drive shaft universal joints are used on rear-wheel drive vehicles: cross and roller, ball and trunnion, and double-cardan (constant velocity) universal joints.

Cross and Roller Universal Joint

The cross and roller design is the most common type of drive shaft U-joint. It consists of four bearing caps, four needle roller bearings, a cross or journal, grease seals, and snap rings (fig. 5-5).

The bearing caps are held stationary in the drive shaft yokes. Roller bearings fit between the caps and the cross to reduce friction. The cross is free to rotate inside the caps and yokes. Snap rings usually fit into grooves cut in the caps or the yoke bores to secure the bearing caps and bearings. There are several other methods of securing the bearing caps in the yokes. These are bearing covers, U-bolts, and bearing caps.



SHAFT ANGLE IN DEGREES	8	10	15	20	25	30	40
MAXIMUM VARIATION IN DRIVEN SHAFT SPEED PERCENT	2	3	6.9	12.4	19.7	28.9	54

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Figure 5-4.—Speed fluctuations caused by conventional universal joints.

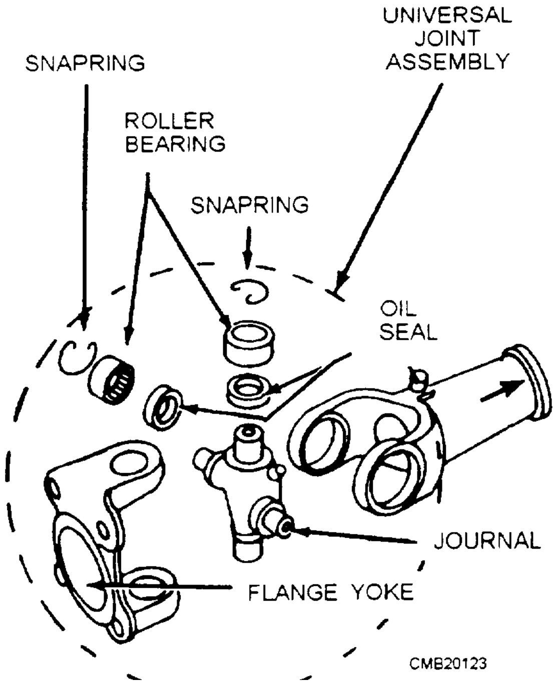


Figure 5-5.—Cross and roller universal joint—disassembled view.

Ball and Trunnion Universal Joint

The ball and trunnion universal joint is a T-shaped shaft that is enclosed in the body of the joint (fig. 5-6). The trunnion ends are each equipped with a ball, mounted in needle bearings. and move freely in grooves in the outer body of the joint, in effect, creating a slip joint. Compensating springs at each end of the drive shaft hold it in a centered position.

Variations in length is permitted by the longitudinal movement of the balls in the body grooves. Angular displacement is allowed by outward movement of the balls on the trunnion pins. This type of universal joint is recognized easily by the flexible dust boot that covers it.

Double-Cardan Universal Joint

The double-cardan universal joint uses two cross and roller joints in tandem to form a single joint (fig. 5-7). The joints are linked through a centering yoke that works in conjunction with a specially designed spring-loaded centering ball. The components are contained within the centering coupling yoke.

As the shafts rotate, the action of the centering ball and yoke acts to maintain an equally divided drive angle between the connected shafts, resulting in a constant drive velocity.

CONSTANT VELOCITY (CV) JOINTS

The speed fluctuations caused by the conventional universal joints do not cause much difficulty in the rear-wheel drive shaft where they have to drive through small angles only. In front-wheel drives, the wheels are cramped up to 30 degrees in steering. For this reason velocity fluctuations present a serious problem. Conventional universal joints would cause

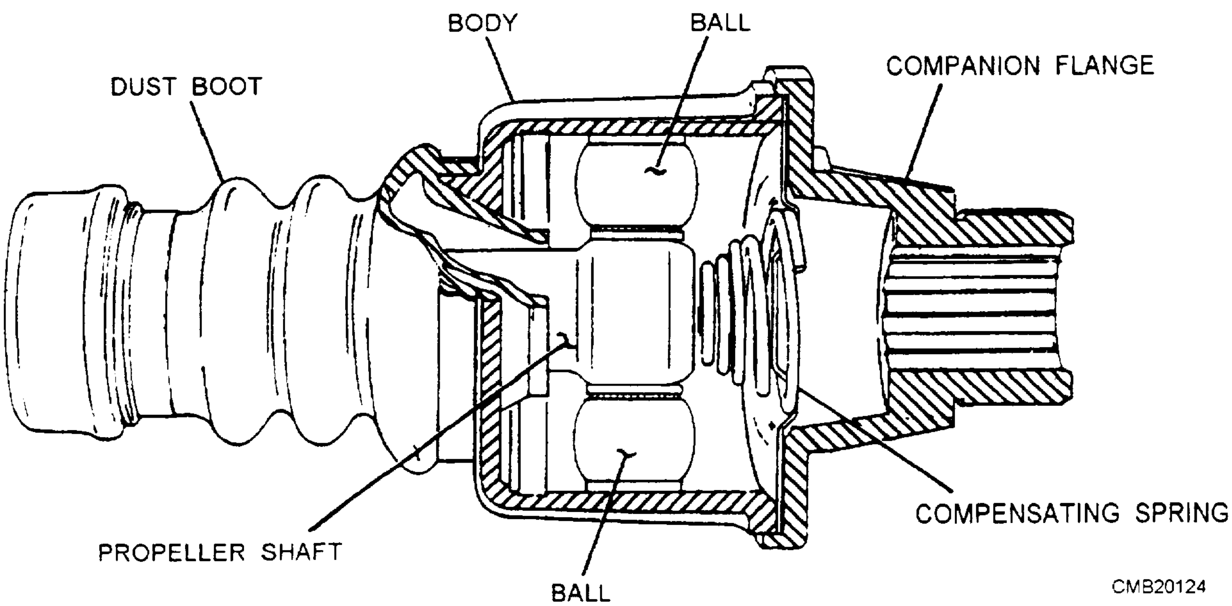


Figure 5-6.—Ball and trunnion universal joint.

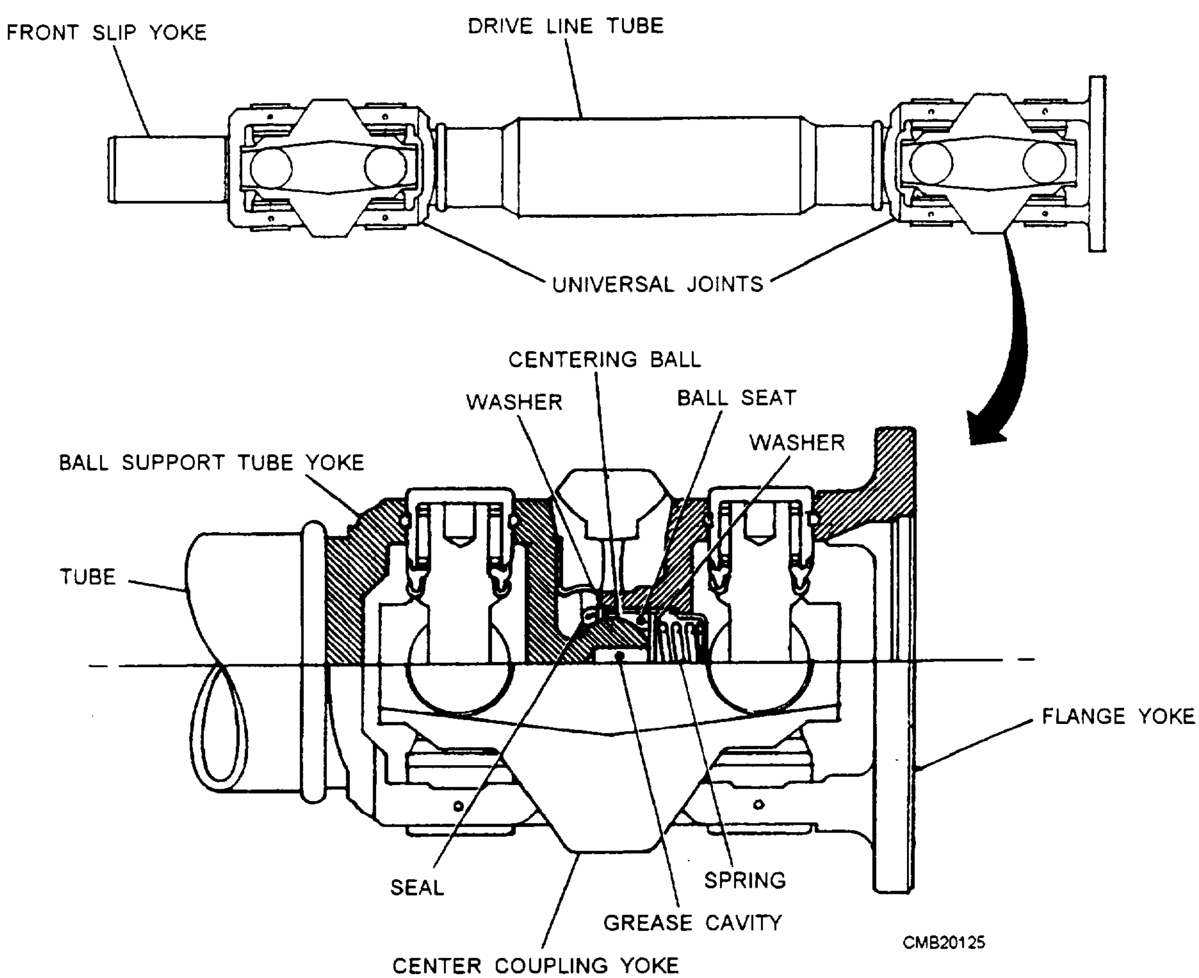


Figure 5-7.—Double-cardan universal joint.

hard steering, slippage, and tire wear each time the vehicle turns a corner. Constant velocity joints eliminate the pulsations because they are designed to be used exclusively to connect the front axle shaft to the driving wheels.

Basic operation of a CV joint is as follows:

- The outboard CV joint is a fixed joint that transfers rotating power from the axle shaft to the hub assembly.
- The inboard CV joint is a sliding joint that functions as a slip joint in a drive shaft for rear-wheel drive vehicles.

The constant velocity joints you will normally encounter are the Rzeppa, Bendix-Weiss, and tripod types.

Rzeppa Constant Velocity (CV) Joint

The Rzeppa constant velocity (CV) joint is a ball-bearing type in which the balls furnish the only points of driving contact between the two halves of the coupling. A Rzeppa CV joint consists of a star-shaped inner race, several ball bearings, bearing cage, outer race or housing, and a rubber boot (fig. 5-8).

The inner race (driving member) is splined to the inner axle shaft. The outer race (driven member) is a spherical housing that is an integral part of the outer shaft; the balls and ball cage are fitted between the two races. The close spherical fit between the three main members supports the inner shaft whenever it is required to slide in the inner race, relieving the balls of any duty other than the transmission of power.

The movement of the balls is controlled by the ball cage. The ball cage positions the balls in a plane at right angles to the two shafts when the shafts are in the same line. A pilot pin, located in the outer shaft, moves the pilot and the ball cage by simple leverage in such a manner that the angular movement of the cage and balls is one half of the angular movement of the driven shaft. For example, when the driven shaft is moved 20

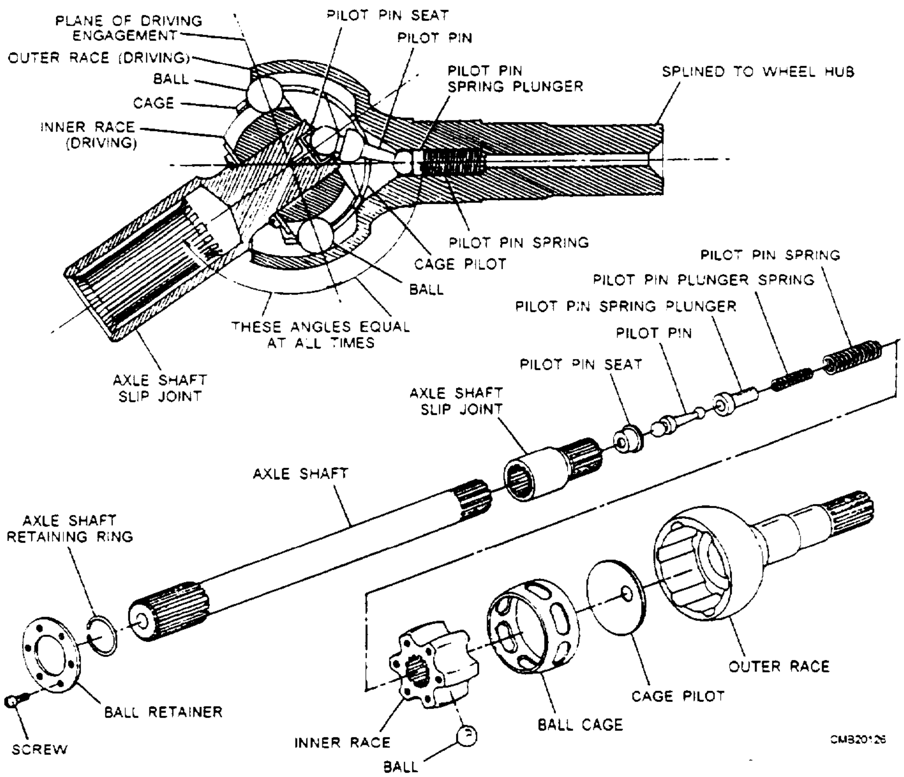


Figure 5-8.—Rzeppa constant velocity (CV) joint.

degrees, the cage and balls move 10 degrees. As a result. the balls of the Rzeppa joint are positioned, from the top view, to bisect the angle formed.

Bendix-Weiss Constant Velocity (CV) Joint

The Bendix-Weiss constant velocity (CV) joint also uses balls that furnish points of driving contact, but its construction differs from that of the Rzeppa in that the balls are a tight fit between two halves of the coupling and that no cage is used (fig. 5-9). The center ball rotates on a pin inserted in the outer race and serves as a locking medium for the four other balls.

The driving contact remains on the plane that bisects the angle between the two shafts; however, it is the rolling friction between the four balls and the

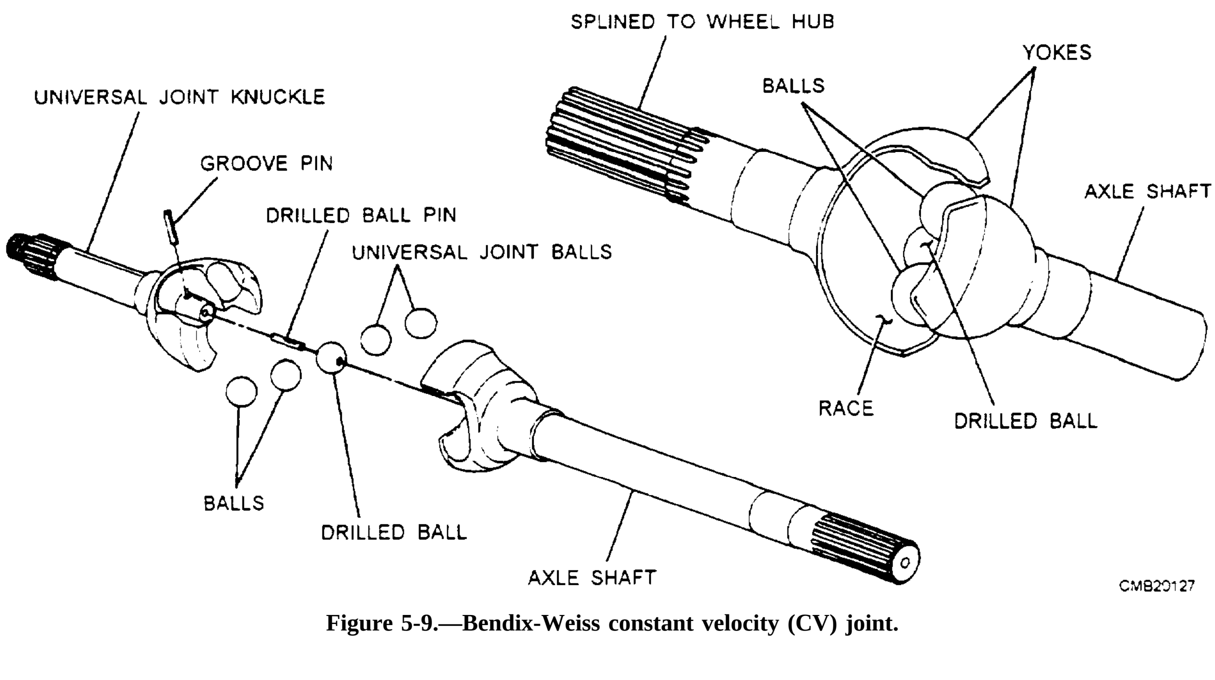


Figure 5-9.—Bendix-Weiss constant velocity (CV) joint.

universal joint housing that positions the balls. When both shafts are in line, that is, at an angle of 180 degrees, the balls lie in a plane that is 90 degrees to the shafts. If the driving shaft remains in the original position, any movement of the driven shaft will cause the balls to move one half of the angular distance. For example, when the driven shaft moves through an angle of 20 degrees, the angle between the two shafts is reduced to 160 degrees. The balls will move 10 degrees in the same direction, and the angle between the driving shaft and the plane in which the balls lie will be reduced to 80 degrees. This action fulfills the requirement that the balls lie in the plane that bisects the angle of drive.

Tripod Joint

A tripod or ball and housing CV joint consists of a spider, usually three balls, needle bearings, outer yoke, and boot. The inner spider is splined to the axle shaft with the needle bearings and three balls fitting around the spider. The yoke then slides over the balls. Slots in the yoke allow the balls to slide in and out and also swivel.

During operation, the axle shaft turns the spider and ball assembly. The balls transfer power to the outer housing. Since the outer housing is connected to the axle stub shaft or hub, power is sent through the joint to propel the vehicle.

CENTER SUPPORT BEARINGS

When two or more drive shafts are connected in tandem, their alignment is maintained by a rubber bushed center support bearing (fig. 5-10). The center support bearing bolts to the frame or underbody of the vehicle. It supports the center of the drive shaft where the two shafts come together.

A sealed ball bearing allows the drive shaft to spin freely. The outside of the ball bearing is held by a thick, rubber, doughnut-shaped mount. The rubber mount prevents vibration and noise from transferring into the operator’s compartment.

A bearing similar to the center support bearing is often used with long drive lines, containing a single drive shaft. This bearing is called a PILLOW BLOCK BEARING. It is commonly used in drive lines that power auxiliary equipment. Its purpose is to provide support for the drive shaft and maintain alignment. When used at or near the center of the shaft, it reduces the whipping tendency of the shaft at high speed or when under heavy loads. The construction of pillow blocks varies. The simplest form is used on solid power takeoff drive shafts, which is no more than a steel sleeve with a bronze bushing.

DRIVE LINE MAINTENANCE

A drive line is subjected to very high loads and rotating speeds. When a vehicle is cruising down the road, the drive shaft and universal joints or constant velocity joints may be spinning at full engine rpm. They are also sending engine power to either the front or rear axle assemblies. This makes drive line maintenance very important.

The drive shafts must be perfectly straight and the joints must be unworn to function properly. If any component allows the drive shafts to wobble, severe vibration, abnormal noises, or even major damage can result.

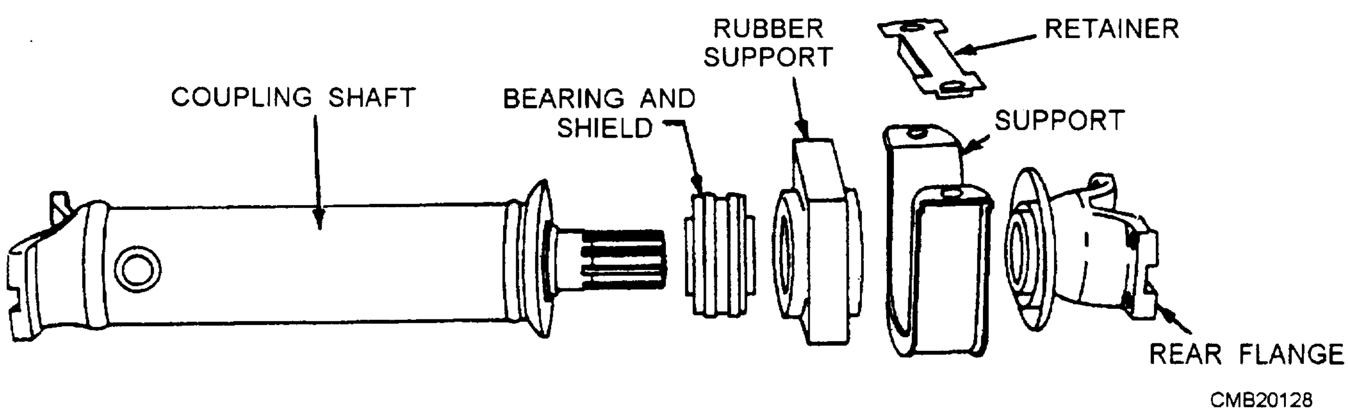


Figure 5-10.—Center support bearing.

Drive Shaft Noises

When operating a vehicle to verify a complaint. keep in mind that other components could be at fault. A worn wheel bearing, squeaking spring, defective tire. transmission, or differential troubles could be at fault. You must use your knowledge of each system to detect which component is causing the trouble.

Drive shaft noises are usually caused by worn U-joints, slip joint wear, or a faulty center support bearing. Drive shaft noises and possible causes are as follows:

- Grinding and squeaking from the drive shaft is frequently caused by worn universal joints. The joints become dry, causing the rollers to wear. The unlubricated, damaged rollers then produce a grinding or squeaking sound, as they operate on the scored cap and cross surfaces.

- A clunking sound, when going from acceleration to deceleration or deceleration to acceleration, may be caused by slip yoke problems. The splines may be worn. The yoke transmission extension housing bushing may also be worn. This will let the yoke move up and down with changes in drive line torque. An excessively worn U-joint or differential problem can also cause a similar noise.

- A whining sound from the drive shaft is sometimes caused by a dry, worn center support bearing. Since this bearing makes complete revolutions. it will make a different sound than a bad universal joint. A high pitched. more constant, whine will usually come from a faulty center support bearing.

Any other abnormal sound should be traced using your knowledge of mechanics. a stethoscope, and the vehicles service manual troubleshooting chart.

Drive Shaft Inspection

To inspect the drive shaft for wear or damage, raise the vehicle and place it on jack stands. Look for undercoating or mud on the drive shaft. Check for missing balance weights, cracked welds, and other drive shaft problems.

To check for working U-joints, wiggle and rotate each U-joint back and forth. Watch the universal joint carefully. Try to detect any play between the cross and the yoke. If the cross moves inside the yoke, the U-joint is worn and needs to be replaced.

Also, wiggle the slip yoke up and down. If it moves in the transmission bushing excessively, either the yoke or the bushing is worn. Inspect the rear yoke bolts for tightness. Make sure the rear motor mount is NOT broken. Look at any condition that can upset the operation of the drive shaft.

If after a thorough check of the drive shaft you fail to determine the problem, notify the shop supervisor. The drive shaft may require detailed measuring (drive shaft runout and drive shaft angle) or have its balance checked.

Universal Joint Service

The universal joints on many automotive vehicles are factory lubricated. However, construction equipment have universal joints that have lubrication fittings that should be lubricated at regular intervals.

Service to universal joints that are factory lubricated is limited to replacement when signs of excessive wear are present. The universal joints provided with lubrication fittings are only lubricated with a hand operated low-pressure grease guns. Use of a high-pressure grease gun will damage the seals, resulting in early failure of the universal joint.

Another area to be concerned with when servicing the universal joints is the slip yoke (joint). Slip yokes may be lubricated from the transmission or lubricated through a lubrication fitting.

NOTE

Always consult the manufacturer's service manual for lubrication intervals and proper lubricants to be used.

A worn universal joint is the most common drive line problem, causing squeaking, grinding, clunking, or clicking sounds. The grease inside the joint can dry out. The roller bearings will wear small indentations in the cross. When the bearings try to roll over these dents, a loud metal-on-metal grinding or chirp sound can result.

Quite often, a worn U-joint is discovered when the transmission is placed in REVERSE. When the vehicle is backed up, the roller bearing is forced over the wear indentation against normal rotation. When this occurs, the rollers will catch on the sharp edges in the worn joint, causing even a louder sound.

UNIVERSAL JOINT DISASSEMBLY.—The universal joint may require removal and disassembly to enable you to check the condition of the joint physically. Steps for the removal and disassembly of a U-joint are as follows:

1. Raise the vehicle and place it on jack stands.
2. Scribe the alignment marks on the differential yoke and universal joint, so drive shaft balance is ensured upon reassembly.
3. Unbolt the rear joint from the differential. If used, also unbolt the center support bearing. Pry the shaft forward and lower the shaft slightly.

CAUTION

Do NOT allow the full weight of the drive shaft to hang from the slip yoke. Support the drive shaft to prevent damage to the extension housing, rear bushing, and front U-joint.

4. Wrap the tape around the caps to prevent them from falling off and spilling the roller bearings.
5. Slide the drive shaft out of the transmission. If the transmission lubricant begins to leak, install a plastic plug into the extension housing.
6. Before disassembling the universal joint, especially constant velocity joints, scribe mark each component. The marks will show you how to reassemble the joint.
7. Clamp the drive shaft yoke in a vise. Do NOT clamp the weaker center section of the drive shaft or it will bend. If used, remove the snap rings, using a screwdriver, snap-ring pliers, or needle nose pliers.

CAUTION

Wear safety glasses to protect your eyes in case the snap rings fly out of the universal joint during removal.

8. Use two sockets—one LARGER than the bearing cap and one SMALLER than the bearing cap. Place the SMALLER socket on the bearing cap of the universal joint (fig. 5-11). The LARGER socket is to be placed over the outside diameter of the bearing cap on the opposite side of the joint (fig. 5-11).
9. With both sockets and the universal inside the vise, slowly tighten the vise to force the bearing caps out of the yoke. Use the same procedure on the remaining bearing caps, as required.

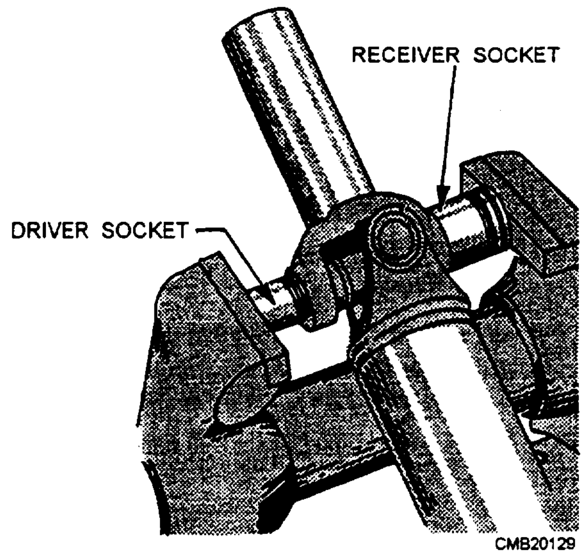


Figure 5-11.—Universal joint removal.

Normally, a universal joint is replaced anytime it is disassembled. However, if the joint is relatively new, you can inspect, lubricate, and reassemble it.

During the inspection, clean the roller bearings and other parts in solvent. Then check the cross and rollers for signs of wear. If the slightest sign of roughness or wear is found on any part, REPLACE the U-joint.

UNIVERSAL JOINT REASSEMBLY.—Once the U-joint has be cleaned and inspected and found to be in a serviceable condition, it must be reassembled. Steps for reassembling a U-joint are as follows:

1. Pack the roller bearings in high-temperature grease. A good method of keeping the bearing in place is to fill the bearing cap with grease.
2. Position the cross inside the yoke. Align your marks. Then fit the bearing caps into each end of the yoke.
3. Center the cross partially into each cap to keep the roller bearing from falling.
4. Place the assembly in a vise. Tighten the vise so that the bearing caps are forced into the yoke.

WARNING

If the bearing cap fails to press into place with normal pressure, disassemble the joint and check the roller bearings. It is easy for a roller bearing to fall and block cap installation. If you try to force the cap with excess pressure, the universal and drive shaft could be damaged.

5. Press the caps fully into position by placing a small socket on one bearing cap. Tighten the vise until the cap is pushed in far enough to install the snap ring. With one snap ring in place, use the socket to force the other cap into position. Install its snap ring.
6. Repeat this procedure on the other universal joint, if needed.

After assembly, check the action of the U-joint. Swing it back and forth into various positions. The joint should move freely, without binding. Double-check that all snap rings have been installed properly. Once the U-joint has be checked and is working properly, reinstall the drive shaft back into the vehicle as follows:

1. Wipe off the outside slip yoke and place a small amount of grease on the internal splines. Align the marks and slide the yoke into the rear of the transmission.
2. Push the slip yoke all the way into the extension housing and position the rear U-joint at the differential.
3. Pull back on the drive shaft and center the rear universal properly. Check your rear alignment marks.
4. Install the U-bolts, bearing caps, or yoke bolts to secure the rear universal joint.
5. With the rear universal joint secured, lower the vehicle to the ground.
6. Test-drive the vehicle for proper operation. Check for unusual noises, vibration, and other abnormalities.

Constant Velocity Joint Service

Constant velocity joint service requires the disassemble of the joint. Refer to the service manual for the vehicle when servicing a CV joint. The manual will give special detailed directions that are required depending on the type of joint.

Once the CV joint is disassembled, obtain a CV joint repair kit (usually includes new joint components, grease, boot, and bootstraps). When the joint is being assembled, refer back to the service manual for detailed directions.

WARNING

Always use the recommended type of grease on a CV joint. The wrong type of grease will cause boot deterioration and joint failure. CV joint kits provide the correct type and amount of grease required.

After reassembling the CV joint, fit the boot over the joint. Make sure the boot ends fit into their grooves. Install the bootstraps. Do not overtighten the straps, as they may cut the boot or break.

Center Support Bearing Service

The center support bearing is normally prelubricated and sealed at the factory. However, some support bearings have lubrication fittings and require lubrication at regular intervals. Even though lubrication extends the useful life of the bearing, they eventually wear out. The first indication of support bearing failure is excessive chassis vibration at low speed. This is caused by the bearing turning with the drive shaft in the rubber support.

When a faulty bearing is suspected, it should be inspected for wear and damage. If the rubber support shows any evidence ofhardening, cracking, or tearing, it should be replaced.

Should you encounter a faulty support bearing, replacement procedures are usually limited to separating the drive shafts, unbolting the bearing support from the frame or cross member, and sliding the bearing and support assembly from the shaft.

If only the bearing is available from the parts room, disassemble the unit by gently prying the bearing out of the rubber support. Next, remove the dust shield from the bearing. All parts that are to be reused should be cleaned. When the bearing is being replaced, some manufacturers recommend that waterproof grease be placed on both sides of the bearing, not for a lubricant but to exclude water and dust from the bearing. Install the dust shield and press the new bearing into the support.

Before securing the bearing support to the frame or cross member, check the service manual to determine if shims are required for alignment purposes. When reassembling support bearings, you should exercise care to ensure that proper alignment of the drive line is maintained. This will prevent abnormal wear of the universal joints.

REVIEW 1 QUESTIONS

Q1. What are the four functions of a drive line assembly?

Q2. The movement of the rear axle assembly also causes the distance between the rear axle and transmission to change. (T/F)

Q3. When is a center support bearing needed and why?

Q4. Grinding or squeaking from the drive shaft is frequently caused by ____________

Q5. How do you check for worn universal joints?

Q6. If a universal joint fails to press together with normal force, it is possible that one of the needle bearings has fallen out of place. (T/F)

DIFFERENTIALS

Learning Objective: Identify differential design variations. Describe the principles of the limited slip differential. Explain basic service and repair of a differential. Explain the adjustment of the ring and pinion gears.

Another important unit in the power train is the differential, which is driven by the final drive. The differential is located between the axles and permits one axle to turn at a different speed from that of the other. The variations in axle speed are necessary when a vehicle rounds a corner or travels over uneven ground. At the same time, the differential transmits engine torque to the drive axles. The drive axles are on a rotational axis that is 90 degrees different than the rotational axis of the drive shaft.

DIFFERENTIAL CONSTRUCTION

A differential assembly uses drive shaft rotation to transfer power to the axle shafts. The term *differential* can be remembered by thinking of the words *different* and axle. The differential must be capable ofproviding torque to both axles, even when they are turning at different speeds. The differential assembly is constructed from the following: the differential carrier, the differential case, the pinion gear, the ring gear, and the spider gears (fig. 5-12).

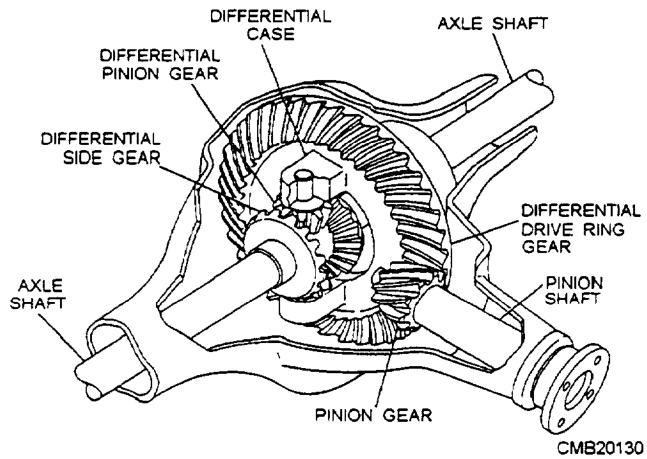


Figure 5-12.—Conventional differential.

Differential Carrier

The differential carrier provides a mounting place for the pinion gear, the differential case, and other differential components. There are two types of differential carriers: the removable type and the integral (unitized) type.

- REMOVABLE TYPE—a carrier that bolts to the front of the axle housing. Stud bolts are installed in the housing to provide proper carrier alignment. A gasket is installed between the carrier and the housing to prevent leakage.
- INTEGRAL TYPE—a carrier that is constructed as part of the axle housing. A stamped metal or cast aluminum cover bolts to the rear of the carrier for inspection of the gears.

Differential Case

The differential case holds the ring gear, the spider gears, and the inner ends of the axles. It mounts and rotates in the carrier. Case bearings fit between the outer ends of the differential case and the carrier.

Pinion Gear

The pinion gear turns the ring gear when the drive shaft is rotating. The outer end of the pinion gear is splined to the rear U-joint companion flange or yoke. The inner end of the pinion gear meshes with the teeth on the ring gear.

The pinion gear is mounted on tapered roller bearings that allow the pinion gear to move freely on the carrier. Either a crushable sleeve or shims are used to preload the pinion gear bearings. Some differentials use a pinion pilot bearing that supports the extreme inner end of the pinion gear. The pinion pilot bearing assists the tapered roller bearings in supporting the pinion gear during periods of heavy loads.

Ring Gear

The pinion gear drives the ring gear. It is bolted securely to the differential case and has more teeth than the pinion gear. The ring gear transfers rotating power through an angle change or 90 degrees.

The ring and pinion gears are a matched set. They are lapped (meshed and spun together with an abrasive compound on the teeth) at the factory. Then one tooth on each gear is marked to show the correct teeth engagement. Lapping produces quieter operation and assures longer gear life.

Spider Gears

The spider gears are a set of small bevel gears that include two axle gears (differential side gears) and hvo pinion gears (differential idler gears). The spider gears mount inside the differential case. A pinion shaft passes through the two pinion gears and case. The two side gears are splined to the inner ends of the axles.

FINAL DRIVE

A final drive is that part of a power transmission system between the drive shaft and the differential. Its function is to change the direction of the power transmitted by the drive shaft through 90 degrees to the driving axles. At the same time. it provides a fixed reduction between the speed of the drive shaft and the axle driving the wheels.

The reduction or gear ratio of the final drive is determined by dividing the number of teeth on the ring gear by the number of teeth on the pinion gear. In passenger vehicles, this speed reduction varies from about 3:1 to 5:1. In trucks it varies from about 5:1 to 11:1. To calculate rear axle ratio, count the number of teeth on each gear. Then divide the number of pinion teeth into the number of ring gear teeth. For example, if the pinion gear has 10 teeth and the ring gear has 30 (30 divided by 10), the rear axle ratio would be 3:1. Manufacturers install *a* rear axle ratio that provides a compromise between performance and economy. The average passenger car ratio is 3.50:1.

The higher axle ratio, 4.11:1 for instance, would increase acceleration and pulling power but would decrease fuel economy. The engine would have to run at a higher rpm to maintain an equal cruising speed.

The lower axle ratio. 3:1, would reduce acceleration and pulling power but would increase fuel mileage. The engine would run at a lower rpm while maintaining the same speed.

The major components of the final drive include the pinion gear, connected to the drive shaft, and a bevel gear or ring gear that is bolted or riveted to the differential carrier. To maintain accurate and proper alignment and tooth contact, the ring gear and differential assembly are mounted in bearings. The bevel drive pinion is supported by two tapered roller bearings, mounted in the differential carrier. This pinion shaft is straddle mounted. meaning that a bearing is located on each side of the pinion shaft teeth. Oil seals prevent the loss of lubricant from the housing where the pinion shaft and axle shafts protrude. As a mechanic, you will encounter the final drive gears in the spiral bevel and hypoid design. as shown in figure 5-13.

Spiral Bevel Gear

Spiral bevel gears have curved gear teeth with the pinion and ring gear on the same center line. This type of final drive is used extensively in truck and occasionally in older automobiles. This design allows for constant contact between the ring gear and pinion. It also necessitates the use of heavy grade lubricants.

Hypoid Gear

The hypoid gear final drive is an improvement or variation of the spiral bevel design and is commonly used in light and medium trucks and all domestic rear-wheel drive automobiles. Hypoid gears have replaced spiral bevel gears because they lower the hump in the floor of the vehicle and improve gear-meshing action.

As you can see in figure 5-13, the pinion meshes with the ring gear below the center line and is at a slight angle (less than 90 degrees). This angle and the use of

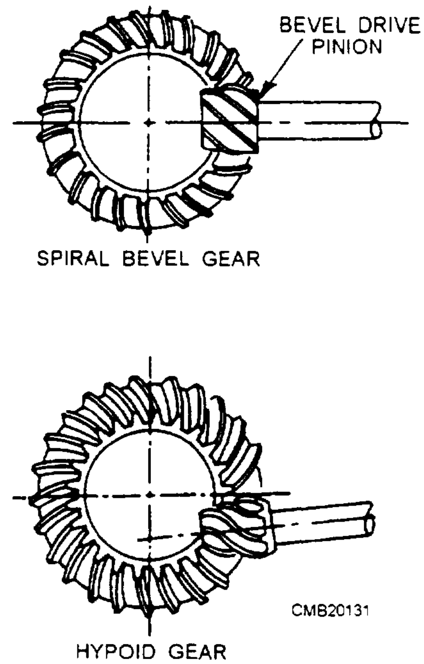


Figure 5-13.—Types of final drives.

heavier (larger) teeth permit an increased amount of power to be transmitted while the size of the ring gear and housing remain constant.

The tooth design is similar to the spiral bevel but includes some of the characteristics of the worm gear. This permits the reduced drive angle. The hypoid gear teeth have a more pronounced curve and steeper angle, resulting in larger tooth areas and more teeth to be in contact at the same time. With more than one gear tooth in contact, a hypoid design increases gear life and reduces gear noise. The wiping action of the teeth causes heavy tooth pressure that requires the use of heavy grade lubricants.

Double-Reduction Final Drive

In the final drives shown in figure 5-13, there is a single fixed gear reduction. This is the only gear reduction in most automobiles and light- and some medium-duty trucks between the drive shaft and the wheels.

Double-reduction final drives are used for heavy-duty trucks. With this arrangement (fig. 5-14) it is not necessary to have a large ring gear to get the necessary gear reduction. The first gear reduction is obtained through a pinion and ring gear as the single fixed gear reduction final drive. Referring to figure 5-14, notice that the secondary pinion is mounted on the primary ring gear shaft. The second gear reduction is the result of the secondary pinion which is rigidly attached to the primary ring gear, driving a large helical gear which is attached to the differential case. Double-reduction final drives may be found on military design vehicles, such as the 5-ton truck. Many commercially designed vehicles of this size use a single- or double-reduction

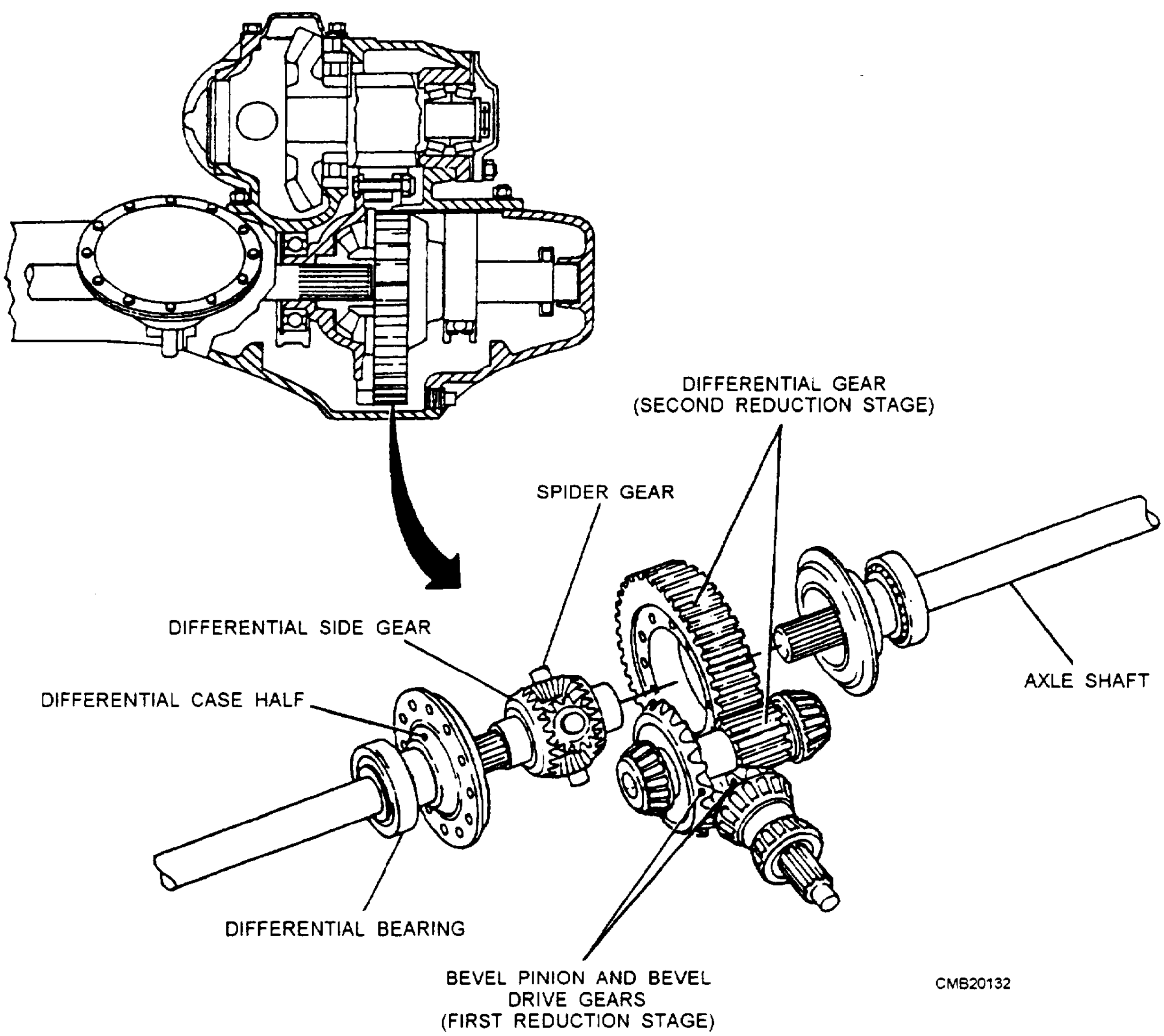


Figure 5-14.—Double-reduction final drive.

final drive with provisions for two speeds to be incorporated.

Two-Speed Final Drive

The two-speed or dual-ratio final drive is used to supplement the gearing of the other drive train components and is used in vehicles with a single drive axle (fig. 5-15). The operator can select the range or speed of this axle with a button on the shifting lever of the transmission or by a lever through linkage.

The two-speed final drive doubles the number of gear ratios available for driving the vehicle under various load and road conditions. For example, a vehicle with a two-speed unit and a five-speed transmission, ten different forward speeds are available. This unit provides a gear ratio high enough to permit pulling a heavy load up steep grades and a low ratio to permit the vehicle to run at high speeds with a light load or no load.

The conventional spiral bevel pinion and ring gear drives the two-speed unit, but a planetary gear train is placed between the differential drive ring gear and the differential case. The internal gear of the planetary gear train is bolted rigidly to the bevel drive gear. A ring on which the planetary gears are pivoted is bolted to the differential case. A member, consisting of the sun gear and a dog clutch, slides on one of the axle shafts and is controlled through a button or lever accessible to the operator.

When in high range, the sun gear meshes with the internal teeth on the ring carrying the planetary gears and disengages the dog clutch from the left bearing adjusting ring, which is rigidly held in the differential carrier. In this position, the planetary gear train is locked together. There is no relative motion between the differential case and the gears in the planetary drive train. The differential case is driven directly by the differential ring gear, the same as in the conventional single fixed gear final drive.

When shifted into low range, the sun gear is slid out of mesh with the ring carrying the planetary gears. The dog clutch makes a rigid connection with the left bearing adjusting ring. Because the sun gear is integral with the dog clutch, it is also locked to the bearing adjusting rings and remains stationary. The internal gear rotates the planetary gears around the stationary sun gear, and the differential case is driven by the ring on which the planetary gears are pivoted. This action produces the gear reduction, or low speed, of the axle.

DIFFERENTIAL ACTION

The rear wheels of a vehicle do not always turn at the same speed. When the vehicle is turning or when tire diameters differ slightly, the rear wheels must rotate at different speeds.

If there were a solid connection between each axle and the differential case, the tires would tend to slide, squeal, and wear whenever the operator turned the steering wheel of the vehicle. A differential is designed to prevent this problem (fig. 5-16).

Driving Straight Ahead

When a vehicle is driving straight ahead, the ring gear, the differential case, the differential pinion gears, and the differential side gears turn as a unit. The two differential pinion gears do NOT rotate on the pinion shaft, because they exert equal force on the side gears. As a result, the side gears turn at the same speed as the ring gear, causing both rear wheels to turn at the same speed.

Turning Corners

When the vehicle begins to round a curve, the differential pinion gears rotate on the pinion shaft. This occurs because the pinion gears must walk around the slower turning differential side gear. Therefore, the pinion gears carry additional rotary motion to the faster turning outer wheel on the turn.

Differential speed is considered to be 100 percent. The rotating action of the pinion gears carries 90 percent of this speed to the slowing mover inner wheel and sends 110 percent of the speed to the faster rotating outer wheel. This action allows the vehicle to make the turn without sliding or squealing the wheels.

LIMITED SLIP DIFFERENTIALS

The conventional differential delivers the same amount of torque to each rear wheel when both wheels have equal traction. When one wheel has less traction than the other, for example, when one wheel slips on ice, the other wheel cannot deliver torque. All turning effort goes to the slipping wheel. To provide good even traction even though one wheel is slipping, a limited slip differential is used in many vehicles. It is very similar to the standard unit but has some means of preventing wheel spin and loss of traction. The standard differential delivers maximum torque to the wheel with minimum traction. The limited slip differential delivers maximum torque to the wheel with maximum traction. Other names for a limited slip

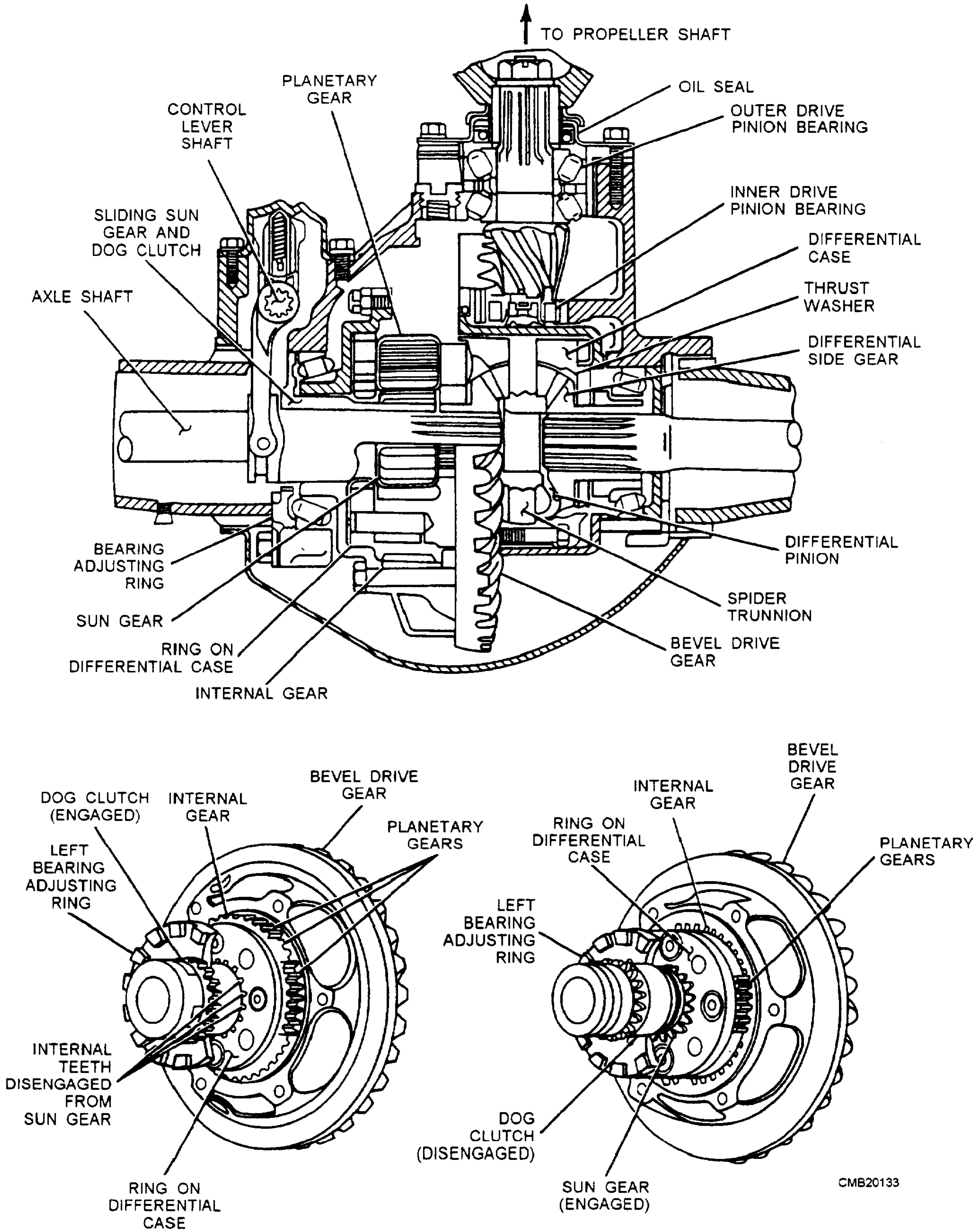


Figure 5-15.—Two speed final drive.

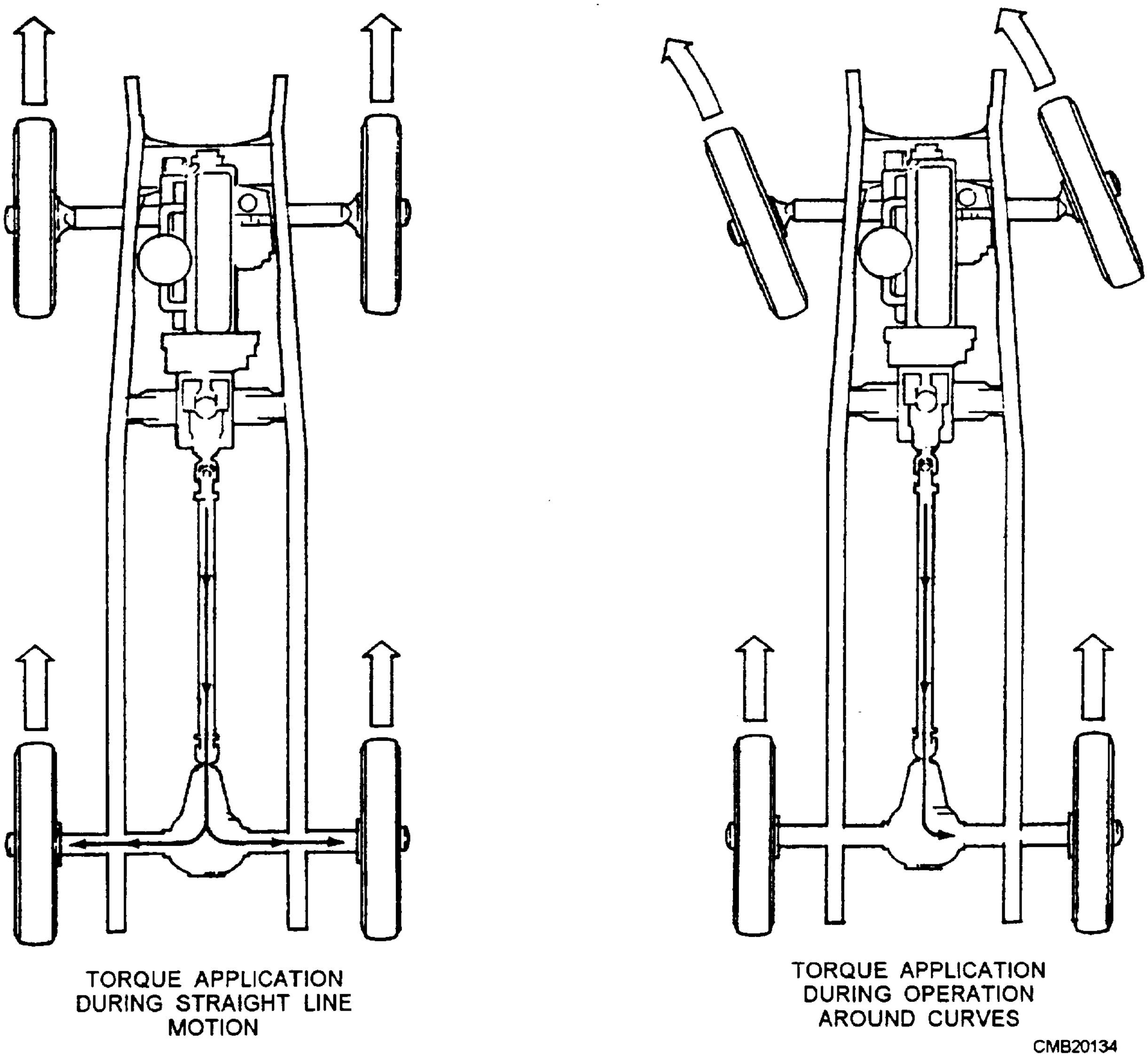


Figure 5-16.—Differential operation.

differential are posi-traction, sure-grip, equal-lock, and no-spin.

Clutch Pack Limited Slip Differential

The clutch pack limited slip differential (fig. 5-17) uses a set of friction discs and steel plates to lock the axles together whenever one drive wheel experiences uncontrolled slippage. The friction discs are sandwiched between the steel plates inside the differential case. The friction disc is splined and turns with the differential side gears. The steel plates turn with the differential case.

Springs (bellville springs, coil springs, or leaf springs) force the friction disc and steel plates together. As a result, both rear axles try to turn with the differential case.

Spring force and thrust action of the spider gears applies the clutch pack. Under high torque conditions, the rotation of the differential pinion gears PUSHES OUT on the axle side gears. The axle side gears then push on the clutch discs. This action helps lock the disc and keeps both wheels turning.

However, when driving normally, the vehicle can turn a comer without both wheels rotating at the same speed. As the vehicle turns a comer, the inner drive wheel must slow down. The unequal speed between the side gears causes the side gear pinions to walk around the side gears. This walking will cause the outer axle shaft to rotate faster than the differential case, allowing the pinion shaft on the side to slide down a V-shaped ramp. This action releases the outer clutches causing the clutch pack to slip when the vehicle is turning.

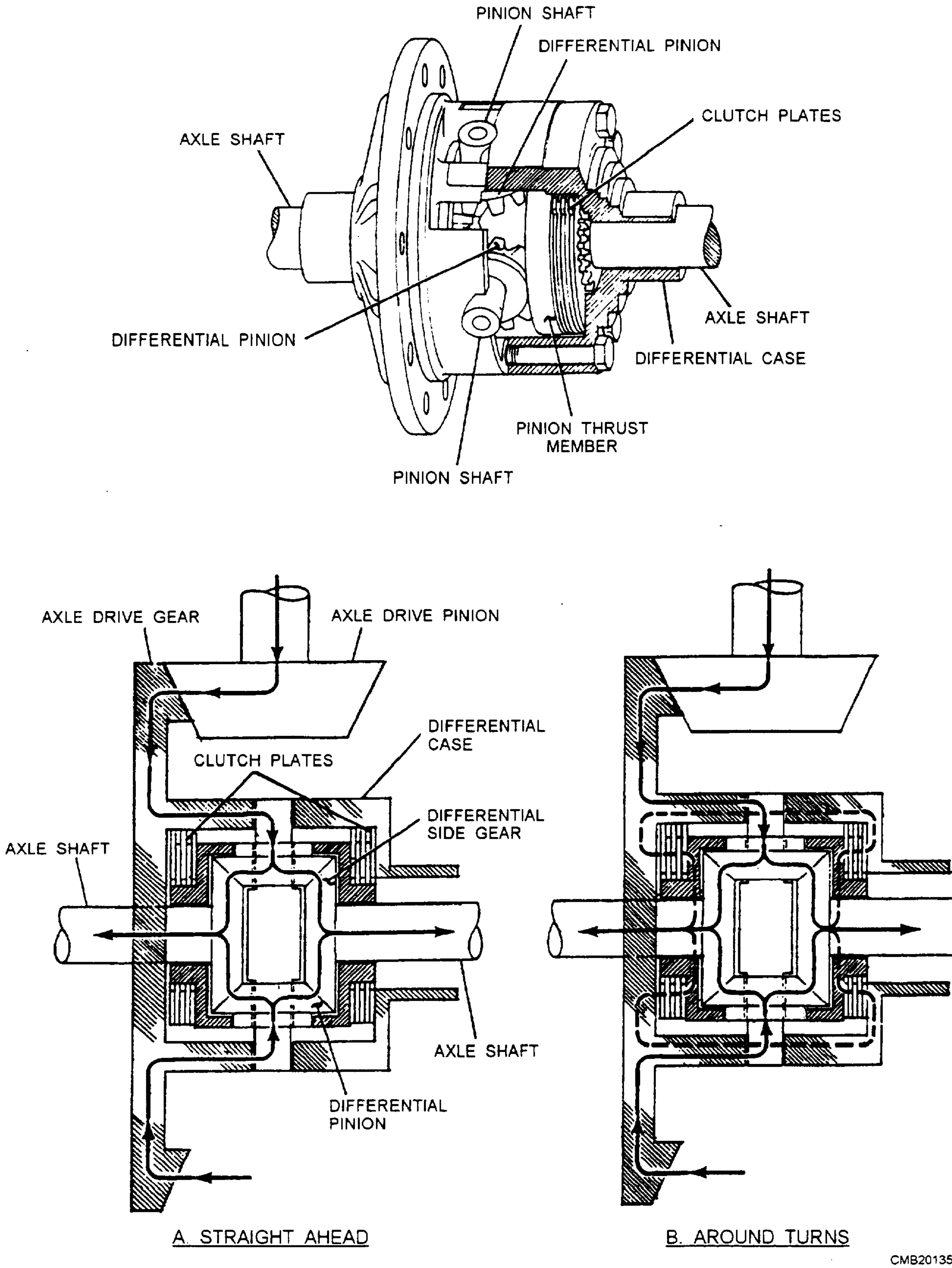


Figure 5-17.—Clutch pack limited slip differential.

Cone Clutch Limited Slip Differential

A cone clutch limited slip differential uses the friction produced by cone-shaped axle gears to provide improved traction (fig. 5-18). These cones fit behind and are splined to the axle shafts. With the axles splined to the cones. the axles tend to rotate with the differential case. Coil springs are situated between the side gears to wedge the clutches into the differential case.

Under rapid acceleration or when one wheel loses traction. the differential pinion gears, as they drive the cones, push outward on the cone gears. This action increases friction between the cones and case, driving the wheels with even greater torque.

When a vehicle goes around a comer, the inner drive wheel must slow down. The unequal speed between the side gears will cause the side gear pinions to walk around the side gears. This walking action causes the outer axle shaft to rotate faster than the differential case. Because the cones have spiral grooves cut into their clutch surfaces, the inner cone will draw itself into the case and lock tight and the outer cone clutch will back itself out of the case. This action allows the outer drive axle to free wheel. The end result is the majority of the engine torque is sent to the inner drive wheel.

DIFFERENTIAL SERVICE AND MAINTENANCE

Differentials in a properly operated vehicle seldom cause any maintenance problems. By maintaining the proper lubrication level and occasionally changing a seal or gasket, the assembly will normally last as long as the vehicle.

The first hint of existing trouble is generally an unusual noise in the axle housing. To diagnose the trouble properly, you must determine the source of the noise and under what operating conditions the noise is most pronounced. Defective universal joints, rough wheel bearings, or tire noises may be improperly diagnosed by an inexperienced mechanic as differential trouble.

Some clue may be gained as to the cause of trouble by noting whether the noise is a growl, hum, or knock; whether it is heard when the vehicle is operating on a straight road, or on turns only; and whether the noise is most noticeable when the engine is driving the vehicle or when it is coasting with the vehicle driving the engine.

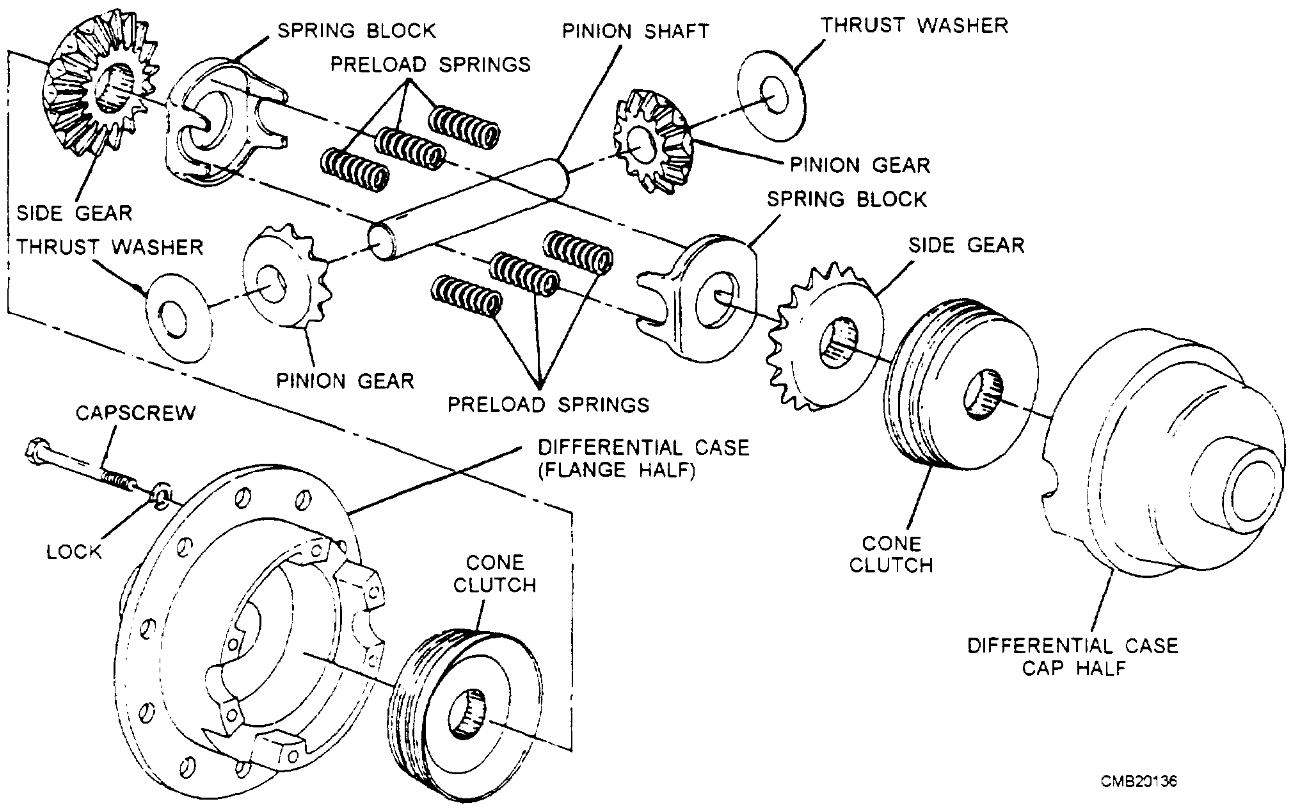


Figure 5-18.—Cone clutch limited slip differential.

A humming noise in the differential generally means the ring gear or pinion needs an adjustment. An improperly adjusted ring gear or pinion prevents normal tooth contact between the gears and therefore produces rapid tooth wear. If the trouble is not corrected immediately, the humming noise will gradually take on a growling sound, and the ring and pinion will probably have to be replaced.

It is very easy to mistake tire noise for differential noise. Tire noise will vary according to the type of pavement the vehicle is being operated on, while differential noise will not. To confirm a doubt as to whether the noise is caused by tire or differential, drive the vehicle over various pavement surfaces. If the noise is present in the differential only when the vehicle is rounding a comer, the trouble is likely to be in the differential case.

If the backlash (clearance) between the ring and pinion is too great, a CLUNKING sound is produced by the gears. For example, when an automatic transmission is shifted into drive, the abrupt rotation of the drive shaft can bring the gears together with a loud thump.

The ring and pinion gears can become worn, scored, out of adjustment, or damaged. The problems can result from prolonged service, fatigue, and from lack of lubricant. You need to inspect the differential to determine whether adjustment or part replacement is required.

A differential identification (ID) number is provided to show the exact type of differential for ordering parts and looking up specifications. The number may be on a tag under one of the carrier or inspection cover bolts; it also may be stamped on the housing or carrier. Use the ID number to find the axle type, axle ratio, make of the unit, and other information located in the service manual.

Differential Lubricant Service

Many vehicle manufacturers recommend that the differential fluid be checked and replaced at specific intervals. To check the fluid level in a differential, remove the filler plug, which is located either in the front or rear of the assembly. The lubricant should be even with the fill hole when hot and slightly below the hole when cold.

When the manufacturer recommends that the differential fluid be replaced, remove the drain plug located on the bottom of the differential housing. Some differentials require the removal of the inspection cover to drain the lubricant. With all the fluid drained, replace the drain plug or inspection cover and refill with the proper lubricant.

NOTE

Always install the correct type of differential lubricant. Limited slip differentials often require a special type of lubricant for the friction clutches.

Differential Removal, Disassembly, and Reassembly

Procedures for removal, disassembly, and reassembly vary depending on the type of differential, make, and model. Always refer to the manufacturer's service manual. However, there are several procedures that relate to almost any type of differential.

To remove a separate carrier differential, perform the following:

- Remove the drive shaft.
- Place a drain pan under the differential. Remove the drain plug and drain the lubricant.
- Unbolt the nuts around the outside of the carrier.
- Force the differential carrier away from the housing.

CAUTION

A differential can be surprisingly heavy. Grasp it securely during removal. If the differential is dropped, painful injuries can occur.

To remove an integral differential, perform the following:

- Remove the drive shaft.
- Place a drain pan under the differential. Remove the inspection cover and drain the lubricant.
- With the cover off, inspect and MARK the individual components as they are removed.

The procedure for repairing a differential will vary with the particular unit. Always refer to the service manual. When using a service to repair a differential, remember the following:

- Check for markings before disassembly. The carrier caps, adjustment nuts, shims, ring and pinion, spider gears, and pinion yoke or flange should be installed exactly as they were removed. If needed. punch mark, label, or scribe these components so they can be reassembled properly.

- Clean all parts carefully and inspect them closely for damage.
- Rotate the pinion and case bearing by hand while checking for roughness. Inspect each bearing and race. Replace the bearing and race as a set if faulty.
- If the pinion gear has a collapsible spacer (device for preloading the pinion bearings), always replace. it.
- To avoid seal damage, use a seal driver. Coat the outside of the seal with a nonhardening sealer. Lubricate the inside of the seal using the proper grade of differential fluid. Make sure the seal lip faces the inside of the differential.
- When tightening the pinion yoke nut, clamp the yoke in a vise or use a special holding bar.
- Replace the ring and pinion gears as a set. Mesh and align the gear timing marks (painted lines or other markings) on the ring and pinion gears. This will match the proper teeth that have been lapped together at the factory.
- Torque all fasteners to specifications. Refer to the service manual for torque values.
- Use new gaskets and/or approved sealer.
- Align all markings during reassembly. If you install the carrier caps backwards, for example, the caps can crush and damage the bearing and races. The differential could fail soon after it is returned to service.
- Use the service manual for detailed directions. Differential designs and repair procedures vary. Special tools and methods are frequently required.

Differential Measurements and Adjustments

Several measurements and adjustments are made when assembling a differential. When “setting up” (measuring and adjusting) a differential. correct bearing preloads and gear clearances are extremely critical. The most important differential measurements and adjustments (fig. 5-19) include the following:

1. Pinion gear depth

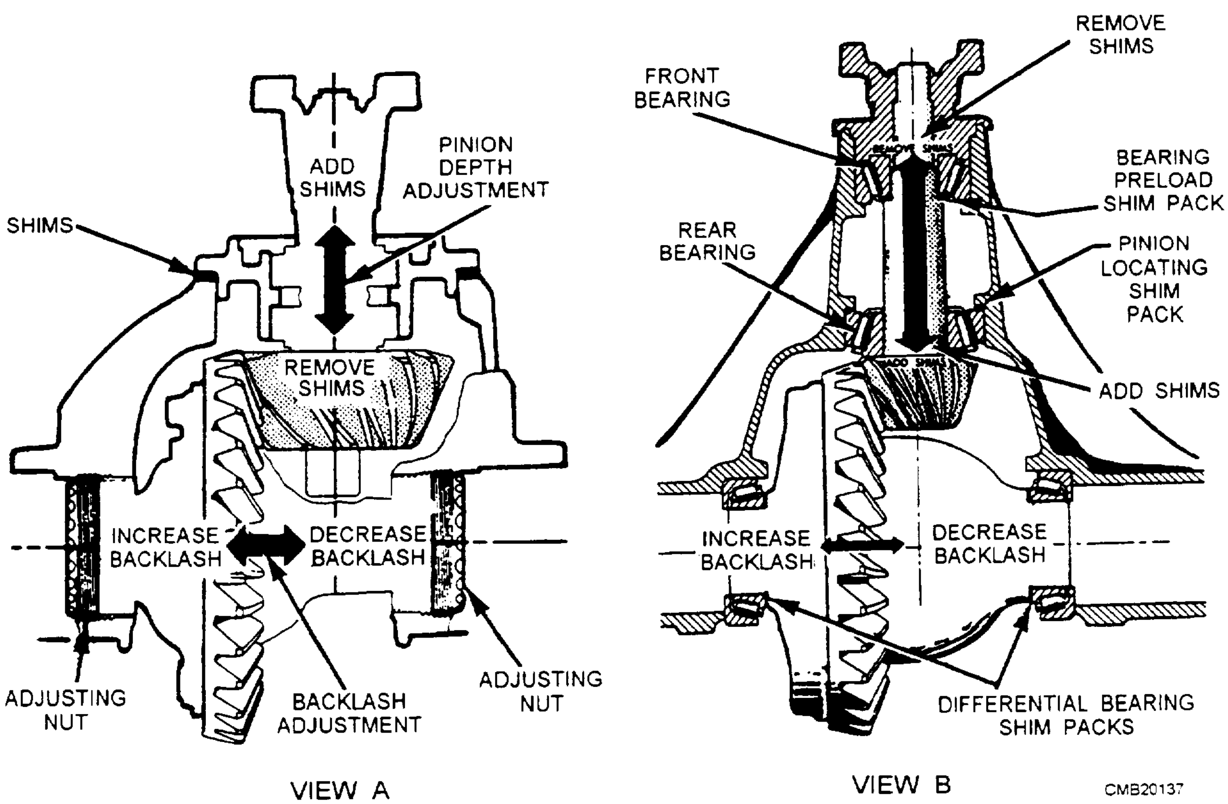


Figure 5-19.—Pinion and ring gear adjustments.

2. Pinion bearing preload

3. Case bearing preload

4. Ring gear runout

5. Ring and pinion backlash

6. Ring and pinion contact pattern

PINION GEAR DEPTH.—The pinion gear depth refers to the distance the pinion gear extends into the carrier. Pinion depth affects where the pinion gear teeth meshes with the ring gear teeth. Pinion gear depth is commonly adjusted by varying shim thickness on the pinion gear and bearing assembly.

PINION BEARING PRELOAD.—The pinion bearing preload is frequently adjusted by torquing the pinion nut to compress a collapsible spacer. The more the pinion nut is torqued, the more the spacer will compress to increase the preload or tightness of the bearings.

With a collapsible spacer, only tighten the pinion nut in small increments. Then measure the pinion preload by turning the pinion nut with an inch-pound torque wrench.

When a solid spacer and pinion nut are used, shims control pinion bearing preload. The pinion nut is torqued to a specific value found in the service manual.

To set pinion bearing preload, use a holding tool to keep the pinion gear stationary. Then a breaker bar or torque wrench can be used to tighten the pinion nut.

CASE BEARING PRELOAD.—The case bearing preload is the amount of force pushing the differential case bearings together. As with pinion bearing preload, it is critical.

If preload is too low (bearings too loose), differential case movement and ring and pinion gear noise can result. If preload is too high (bearings too tight), bearing overheating and failure can result.

When adjusting nuts are used, the nuts are typically tightened until all of the play is out of the bearings. Then each nut is tightened a specific portion of a turn to preload the bearings. This is done when adjusting backlash.

When shims are used, a feeler gauge is used to check side clearance between the case bearing and the carrier. This action will let you calculate the correct shim thickness to preload the case bearings. Refer to the service manual for special equipment and procedures.

RING GEAR RUNOUT.—The ring gear runout is the amount of wobble or side-to-side movement produced when the ring gear is rotated. Ring gear runout must not be beyond the manufacturer's specifications.

To measure ring gear runout, mount a dial indicator against the back of the ring gear (fig. 5-20). The indicator stem should be perpendicular to the ring gear surface. Then turn the ring gear and note the indicator reading. If the ring gear is within specifications, locate a position on the ring gear that indicates ONE HALF of the maximum runout on the gauge. Mark the gear at that point. Then rotate the ring gear until the teeth on the opposite side of the gear from the mark are in mesh with the pinion gear.

If ring gear runout is excessive, check the ring gear mounting and differential case runout. If not a mounting problem, replace either the ring gear and pinion or the case as needed.

RING AND PINION BACKLASH.—The ring and pinion backlash refers to the amount of space between the meshing teeth of the gears. Backlash is needed to allow for heat expansion

As the gears operate, they produce friction and heat. This makes the gears expand, reducing the clearance between the meshing teeth of the gears. Without backlash, the ring and pinion teeth can jam into each other and fail in a very short period of time. However, too much ring and pinion backlash can cause gear noise (whirring, roaring, or clunking).

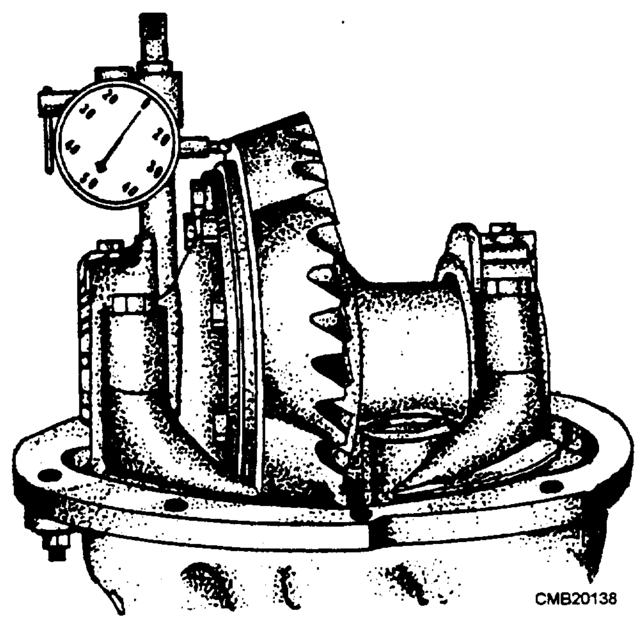


Figure 5-20.—Measuring ring gear runout.

To measure ring and pinion backlash, position a dial indicator stem on one of the ring gear teeth. Then, while holding the pinion gear STATIONARY, wiggle the ring gear back and forth. Indicator needle movement will equal gear backlash. Compare your measurements to the manufacturer's specifications and adjust as needed.

Backlash adjustment can be made by adjusting nuts or by moving shims from one side to the other. To increase backlash, move the ring gear away from the pinion gear. To decrease backlash, move the ring gear towards the pinion gear.

RING AND PINION TOOTH CONTACT PATTERN.—The ring and pinion tooth contact pattern is used to double-check ring and pinion adjustment.

To check the accuracy of your adjustments, coat the ring gear teeth with a thin coat of red lead, white grease, hydrated ferric oxide (yellow oxide or iron), or Prussian blue. Turn the ring gear one way and then the other to rub the teeth together, producing a contact pattern on the teeth. Carefully note the contact pattern that shows up on the teeth where the substance used has been wiped off.

A good contact pattern is one located in the center of the gear teeth (fig. 5-21). Figure 5-21 shows several ring and pinion gear contact patterns. Study each and note the suggested correction for the faulty contact. Note the names of the areas on the ring gear. These include the following:

- TOE (narrow part of the gear tooth)
- HEEL (wide part of the gear tooth)
- DRIVE SIDE (convex side of the gear tooth)
- COAST SIDE (concave side of the gear tooth)

When used gears are adjusted properly, the contact pattern will vary from that of new gears. The important thing to keep in mind with used gears is that the pattern should be closer to the toe than the heel of the tooth, as shown in figure 5-21. Notice that the ideal tooth pattern on new teeth is uniform on both sides, whereas the used gear indicates considerably more contact on the coasting side.

Once you have obtained the proper adjustment on the ring and pinion, bolt the carrier housing in place. Make sure you use a new gasket. Tighten the bolts according to the manufacturer's specifications to prevent them from working loose. Reinstall the axle shafts and new gaskets. Reconnect the drive shaft and fill the axle housing with the proper lubricant.

REVIEW 2 QUESTIONS

Q1. The ____________ must be capable of providing torque to both axles when turning comers.

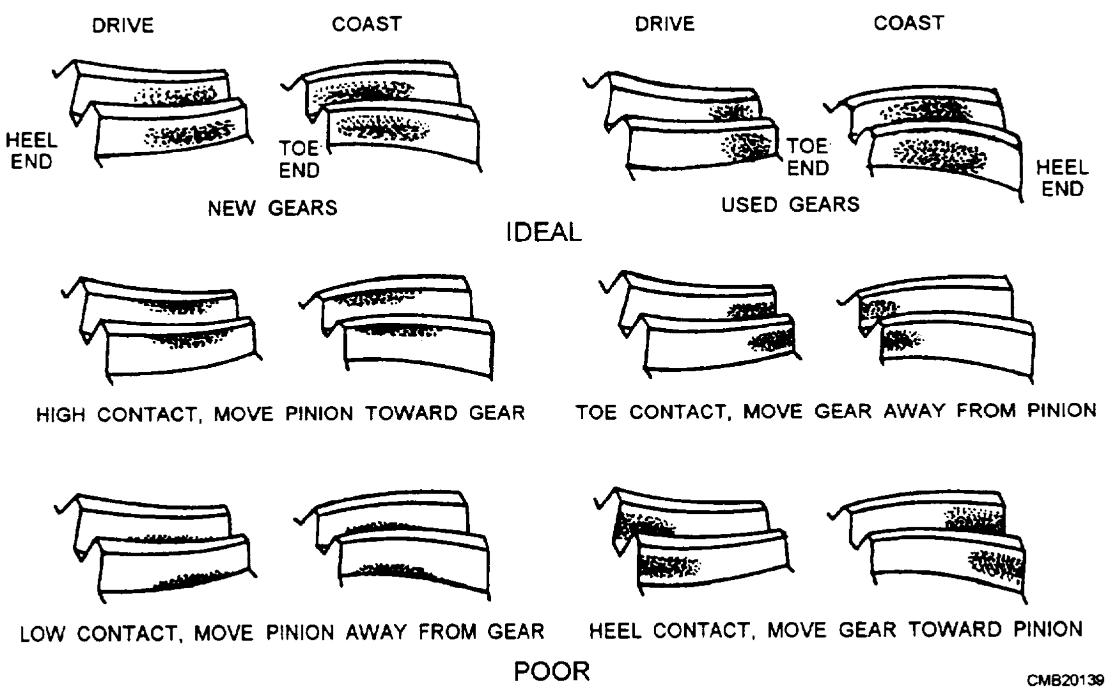


Figure 5-21.—Tooth contact patterns.

Q2. An integral carrier is constructed as part of the axle housing. (T/F)

Q3. Rear axle ratio is determined by comparing the number of teeth on the_______ _______ to the number of teeth on the _______ ______ .

Q4. Excess ring and pinion backlash can cause a "clunking" sound when an automatic transmission is placed in drive. True/False

Q5. _________ _______ ________often require a lubricant that is compatible with friction clutches.

Q6. Ring and pinion preload is a common differential adjustment. (T/F)

DRIVE AXLES

Learning Objective: Identify the parts of the rear drive axle and front drive axle. List the function of the rear axle. Compare the different types of axles. Describe the procedures for replacing axle bearings and seals.

Axles are classified as either LIVE or DEAD. The live axle is used to transmit power. The dead axle only serves as a support for part of the vehicle while providing a mounting for the wheel assembly. Many commercial trucks and truck-tractors have dead axles on the front, whereas practically all passenger vehicles use independent front-wheel suspensions and have no front axles.

The shaft in a live axle assembly may or may not actually support part of the weight of a vehicle, but it does drive the wheels connected to it. A live axle is involved with steering when it is a front drive axle. Some live rear axles are also designed to steer. The rear axle of conventional passenger vehicles is a live axle, while in a four-wheel drive vehicle both front and rear axles are live. In some six-wheel vehicles, all three axles are live axles.

AXLE HOUSING

The axle housing may be of the one-piece or split (banjo) type construction. The former, known as the banjo type because of its appearance, is far more common (fig. 5-22). Notice that openings, both front and rear, are provided in the center housing. The front opening is closed by the differential carrier, while the rear is closed by a spherical cover plate.

Since the assembly must carry the weight of the vehicle, the axle housing in heavy trucks and tractors is a heavy cast unit. In light-duty trucks it may be a combination of cast and steel tube; in general, the center or differential and final drive case is a cast and machined unit, whereas the axle housings themselves may be welded or extruded steel tubing.

Items, such as brake backing plates, mounting flanges, spring mounting plates, and accessory units, may be riveted, welded, or cast into the axle housing. Inspection covers are often provided through which

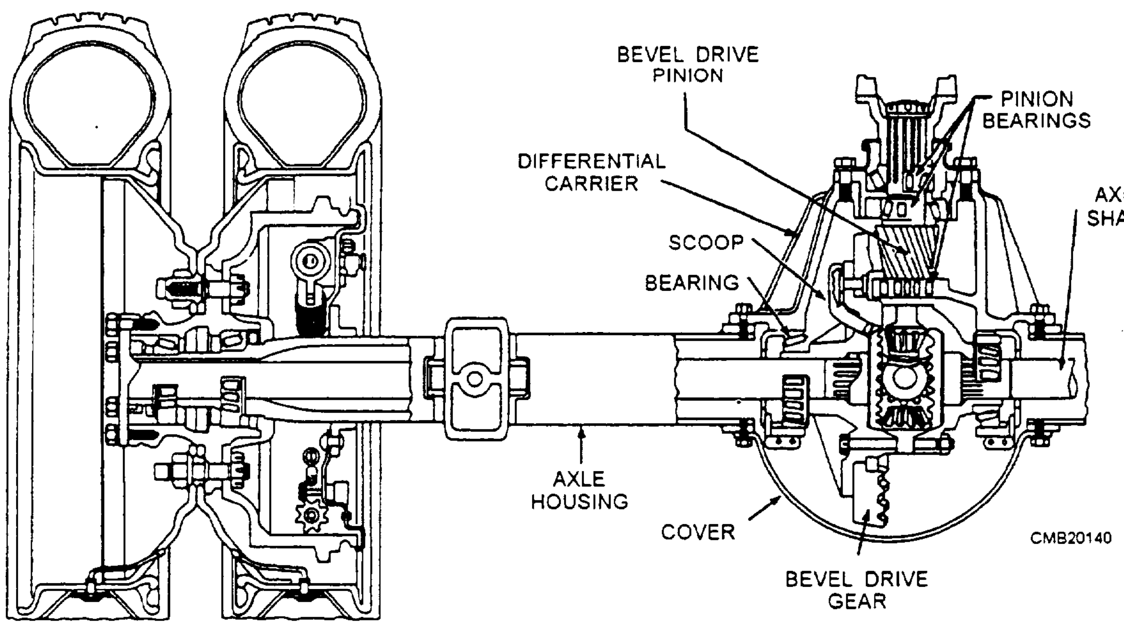


Figure 5-22.—Axle assembly.

the internal parts can be inspected, removed, and installed. Lubricant filler plugs are usually incorporated in the housing inspection cover.

To prevent pressure buildup when the axle becomes warm, a breather vent or valve is provided atop the housing. Without this valve, the resulting pressure could force the axle lubricant past the rear wheel oil seals and damage the brake linings. The valve is constructed so air may pass in or out of the axle housing; however, dirt and moisture are kept out.

REAR DRIVE AXLE

The rear drive axle connects the differential side gears to the drive wheels. The axle may or may not support the weight of the vehicle. Rear axles are normally induction hardened for increased strength. There are several types of rear axle designs: semifloating, three-quarter floating, and full floating. However the semi- and full-floating types are the most common. Most automobiles use the semifloating type, whereas four-wheel drive vehicles and trucks use full floating axles.

Semifloating Axle

The semifloating axle is used in passenger vehicles and light trucks. In vehicles equipped with this type of axle, the shaft, as well as the housing, supports the weight of the vehicle. The inner end of the axle is carried by the side gears in the differential housing. This relieves the axle shafts of the weight of the differential and the stresses caused by its operation that are taken by the axle housing. The inner ends of the axle transmit only turning effort, or torque, and are not acted upon by any other force.

The outer end is carried by a bearing located between the shaft and the housing. A tapered roller of ball-type bearing transfers the load from the shaft to the housing. The axle shafts take the stresses caused by turning, skidding, or wobbling of the wheels.

The axle shafts (fig. 5-23) are flanged or tapered on the ends. When the tapered axle is used, the brake drum and hub are pressed onto the shafts, using keys to prevent the assemblies from turning on the shafts. In some cases, the outer ends of the shafts may have serrations or splines to correspond with those on the drum and hub assembly. Should the axle break with this type of axle assembly, the wheel can separate from the vehicle.

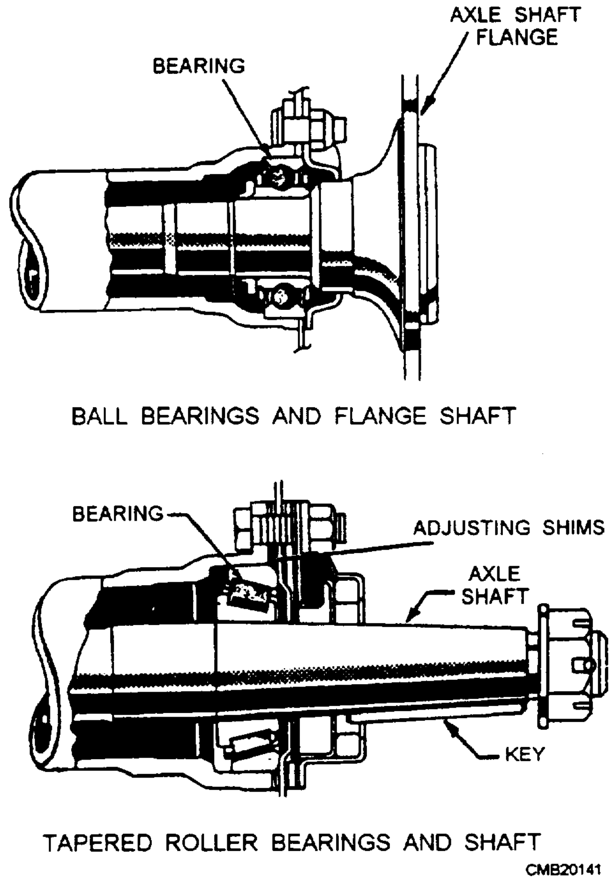


Figure 5-23.—Semifloating axle installation.

Full-Floating Axle

The full-floating axle (fig. 5-24) is used in many heavy-duty trucks. The drive wheel is carried on the outer end of the axle housing by a pair of tapered roller bearings. The bearings are located outside the axle housing. In this way, the axle housings take the full weight of the vehicle and absorb all stresses or end thrust caused by turning, skidding, and pulling. Only the axle shaft transmits torque from the differential.

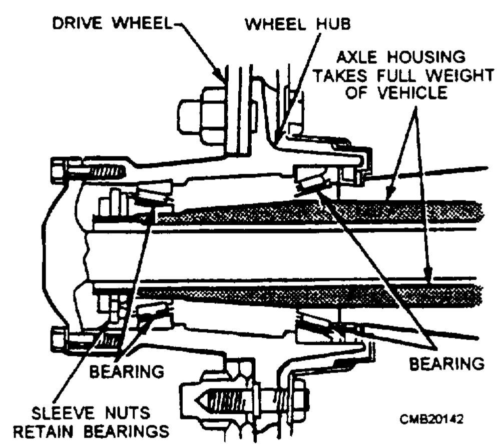


Figure 5-24.—Full-floating axle shaft.

The axle shaft is connected to the drive wheel through a bolted flange. This allows the axle shaft to be removed for servicing without removing the wheel.

FRONT DRIVE AXLE

A front drive axle (fig. 5-25) is very similar to a rear drive axle; however, provisions must be made for steering the front wheels. Power is transmitted from the transfer case to the front axle by a drive shaft. The differential housing may be set off center in the axle housing to permit the drive shaft to pass beside the engine oil pan and maintain sufficient road clearance without excessive height at the front end of the vehicle.

Since the front wheels must turn on the spindle arm pivots, they must be driven by the axle shaft through universal joints, which are located on the outer ends of the axles. The universal joints allow the front wheels and hubs to swivel while still transferring driving power to the hubs and wheels.

The cross and roller joint shown in figure 5-25 is similar to conventional U-joints used on the rear drive shaft, and, in some cases, they are interchangeable.

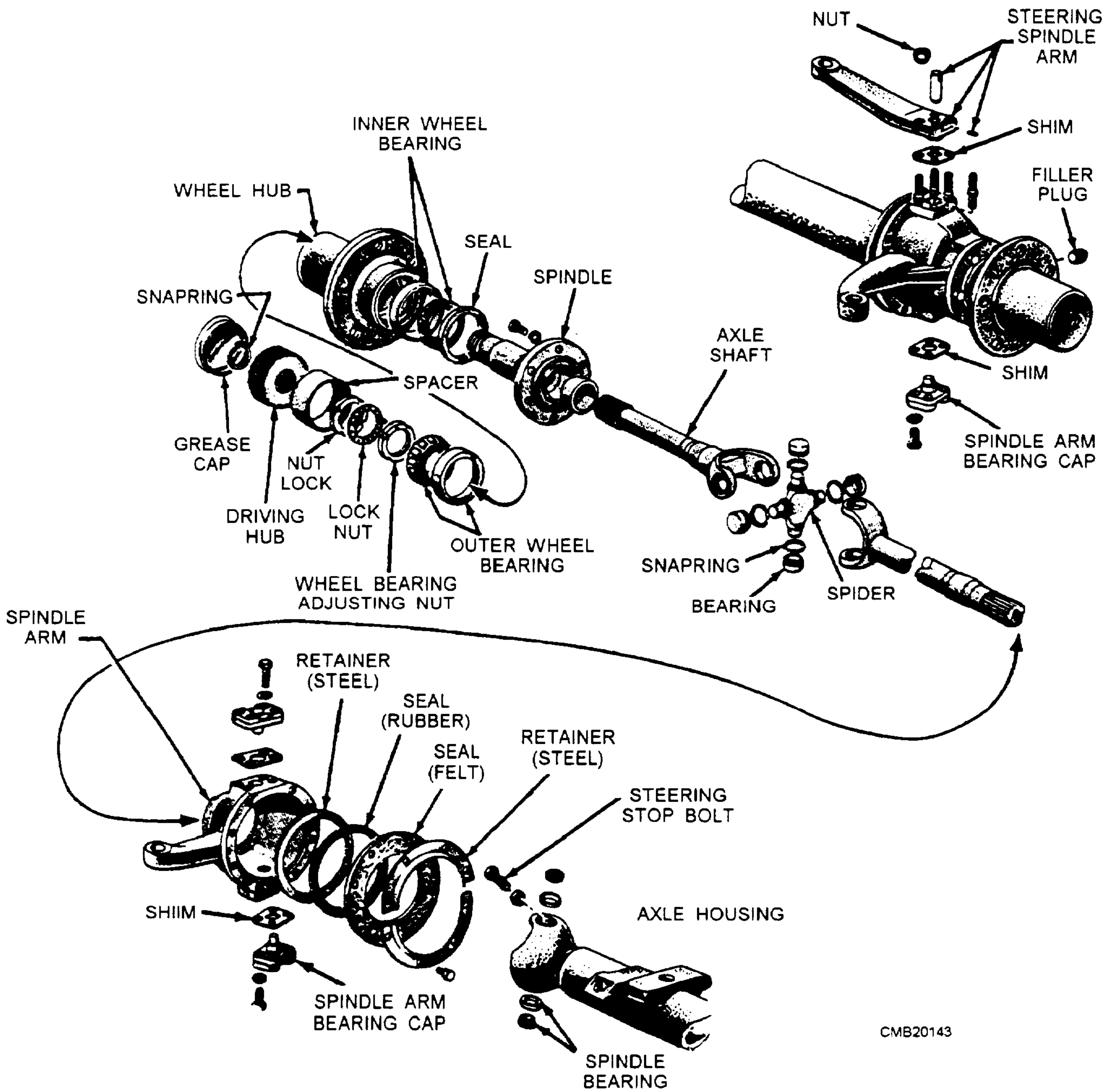


Figure 5-25.—Front drive axle.

This type of U-joint is limited to use in light-duty, vehicles. Other types of universal joints are used in the axles of heavy-duty vehicles. The types you will encounter in military designed vehicles are the Rzeppa and Bendix-Weiss constant velocity joints (fig. 5-26).

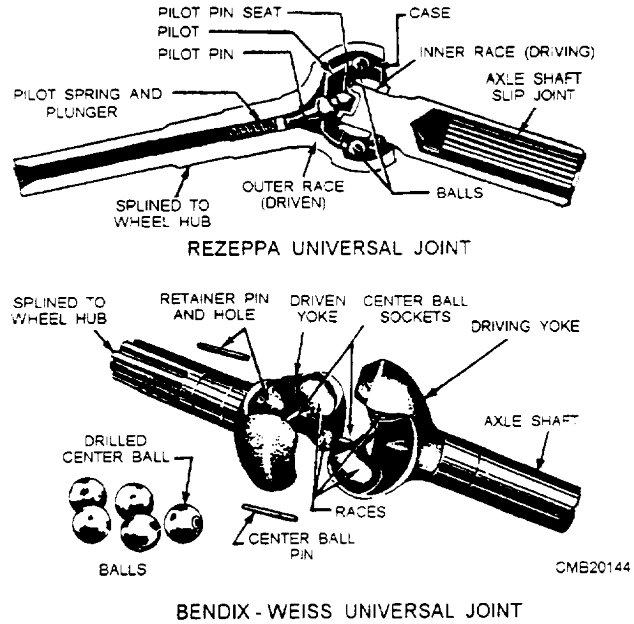


Figure 5-26.—Constant velocity universal joints.

The front drive axle of a four-wheel drive axle requires locking hubs. Locking hubs transfer power from the driving axles to the driving wheels on a four-wheel drive vehicle. There are three basic types of locking hubs, which are as follows:

- MANUAL LOCKING HUB—requires the operator to turn a latch on the hub to lock the hub for four-wheel drive action.
- AUTOMATIC LOCKING HUB—hub locks the front wheels to the axles when the operator shifts into four-wheel drive.
- FULL TIME HUB—front hubs are always locked and drive the front wheels.

Manual and automatic locking hubs are the most common. Used with part-time, four-wheel drive. they enable the drive line to be in two-wheel drive for use on dry pavement. The front wheels can turn without turning the front axles. This allows for increased fuel economy and reduces drive line wear.

FRONT-WHEEL DRIVE (AXLES)

Front-wheel drive axles, also called axle shafts or front drive shafts, transfer power from the transaxle differential to the hubs and wheel of a vehicle. Front-wheel drive axles turn much slower than a drive shaft for a rear-wheel drive vehicle. They turn about one third slower. They are connected directly to the drive wheels and do NOT have to act through the reduction of the axle ring gear and pinion gears.

Front-wheel drive axles typically consists of the following:

- INNER STUB SHAFT—the short shaft splined to the side gears in the differential and connected to the inner universal joint.
- OUTER STUB SHAFT—the short shaft connected to the outer universal joint and the front-wheel hub.
- INTERCONNECTING SHAFT—the center shaft that fits between the two universal joints.

Universal joints that connect the drive axle are called CV joints. The outer CV joint is a FIXED (nonsliding) ball and cage or Rzeppa-type joint that transfers rotating power from the axle shaft to the hub assembly. The inner CV joint is called a PLUNGING (sliding) ball and housing or tripod-type joint that acts like a slip joint in a drive shaft for a rear-wheel drive vehicle.

The plunging action of the inner CV joint allows for a change in distance between the transaxle and the wheel hub. As the front wheels move up and down over bumps in the road, the length of the drive axle (inner joint) must change.

REAR AXLE SERVICE

Rear axle service is needed when an axle bearing is noisy, when an axle is broken, bent, or damaged, or when an axle seal is leaking. The rear axles must be removed to allow removal and repair of the differential assembly.

Axle Bearing Service

Worn or damaged bearings in the carrier or on the axles produce a CONSTANT whirring or humming sound. These bearings, when bad, make about the same sound whether accelerating, decelerating, or coasting. When diagnosing and repairing bearing failures, do the following:

- Check the general condition of all parts during disassembly,, not just the most badly worn or damaged parts.

- Compare the failure to any added information in the service manual and your knowledge of the components operation.
- Determine the cause of the part failure. This helps in assuring that the problems do NOT reoccur.
- Perform all repairs following the manufacturer's recommendations and specifications.

When an axle bearing is faulty, it must be removed from the axle or housing carefully and a new one installed. Depending on the type of axle configuration determines how the bearing is to be removed and replaced. Always refer to the manufacturer's service manual for instructions for the removal and installation of the bearing.

The procedures we will discuss are for a semifloating axle with the bearing and collar pressed on. With the axle removed from the vehicle, proceed as follows:

NOTE

Procedures for axle removal may be found in the service manual for the applicable vehicle.

1. Carefully cut off the collar with a grinder and a sharp chisel.
2. With the collar off, place the axle in a hydraulic press. The driving tool should be positioned so that it contacts the inner bearing race. Use the press to push the axle through the bearing.
3. To install the new bearing, slide the bearing onto the axle. Make sure that the bearing is facing the right direction. Some bearings have a chamfered edge on the inner bearing race, which must face the axle flange.
4. Applying force on the inner bearing race, press the bearing into place by pressing the axle back through the bearing. Then press the collar or retaining ring onto the axle.

CAUTION

Do NOT use a cutting torch to remove the collar and bearing. The heat will weaken and damage the axle.

WARNING

Wear eye and face protection when grinding or chiseling the collar from the axle. Small metal particles may fly into your eyes causing eye damage.

NEVER press on the outer race; bearing damage or explosion will result.

Wear face and eye protection when pressing a bearing on or off the axle shaft. The tremendous pressure used can cause the bearing to shatter and fly into your face with deadly force.

CAUTION

Do **NOT** attempt to press the bearing and collar on at the same time. Bearing and collar damage can result.

Axle Seal Service

Rear axle lubricant leaks can occur at numerous spots, such as the pinion gear seal, carrier or inspection cover gaskets, and at the two axle seals. The leak will show up as a darkened, oily, dirty area below the pinion gear, carrier, or on the inside of the wheel and brake assembly.

Always make sure that a possible axle seal leak is not a brake fluid leak. Touch and smell the wet area to determine the type of leak.

Anytime the axle is removed for service, it is wise to install a new axle seal. This action ensures that the seal between the axle and axle seal is tight. The axle seal is normally force-fitted in the end of the axle housing.

To remove a housing mounted seal, use a slide hammer puller equipped with a hooknose. Place the hook on the metal part of the seal. With an outward jerk on the puller slide, pop out the seal. If a slide hammer puller is not available, a large screwdriver will also work.

CAUTION

Be careful not to scratch the bearing bore in the axle housing.

Make sure that you have the correct new seal. Its outside and inside diameters must be the same as the old seal. A seal part number is stamped on the outside of the seal. This number and the seal manufacturer's name will assist you when ordering a new seal.

Before installing the new seal, coat the outer diameter with a non-hardening sealer. Coat the inside of the seal with lubricant that is the same grade that is in the axle assembly. With the seal facing in the right direction (sealing lip towards inside of the housing), drive the seal squarely into place, using a seal-driving tool. Be careful not to bend the metal seal housing or a leak can result. Make sure the seal is fully seated.

REVIEW 3 QUESTIONS

Q1. What component prevents pressure from building up inside the axle housing?

Q2. What type of axle only transmits torque from the differential and carries no vehicle weight?

Q3. What two types of CV joints are used on front-wheel drive vehicles?

Q4. Worn and damaged axle bearings produce what type of sound(s)?

Q5. What tool is used to remove a housing mounted seal?

TRANSFER CASES

Learning Objective: Explain the operation of a transfer case. Explain basic service operations on a transfer case.

Transfer cases are used in off-road vehicles to divide engine torque between the front and rear driving axles. The transfer case also allows the front driving axle to be disengaged, which is necessary to prevent undue drive line component wear during highway use. Another purpose of the transfer case is to move the drive shaft for the front driving axle off to the side so that it can clear the engine. This arrangement is necessary to allow adequate ground clearance and to allow the body of the vehicle to remain at a practical height. Figure 5-27 shows a typical drive line arrangement with a transfer case.

CONVENTIONAL TRANSFER CASE

A conventional transfer case is constructed similar to a transmission, in that it uses shift forks, splines, gears, shims, bearings, and other components found in manual and automatic transmissions. The transfer case has an outer case made of either cast iron or aluminum that is filled with a lubricant that cuts friction on all moving parts. Seals hold the lubricant in the case and prevent leakage from around the shafts and yokes. Shims are used to set up the proper clearances between the internal components and the case.

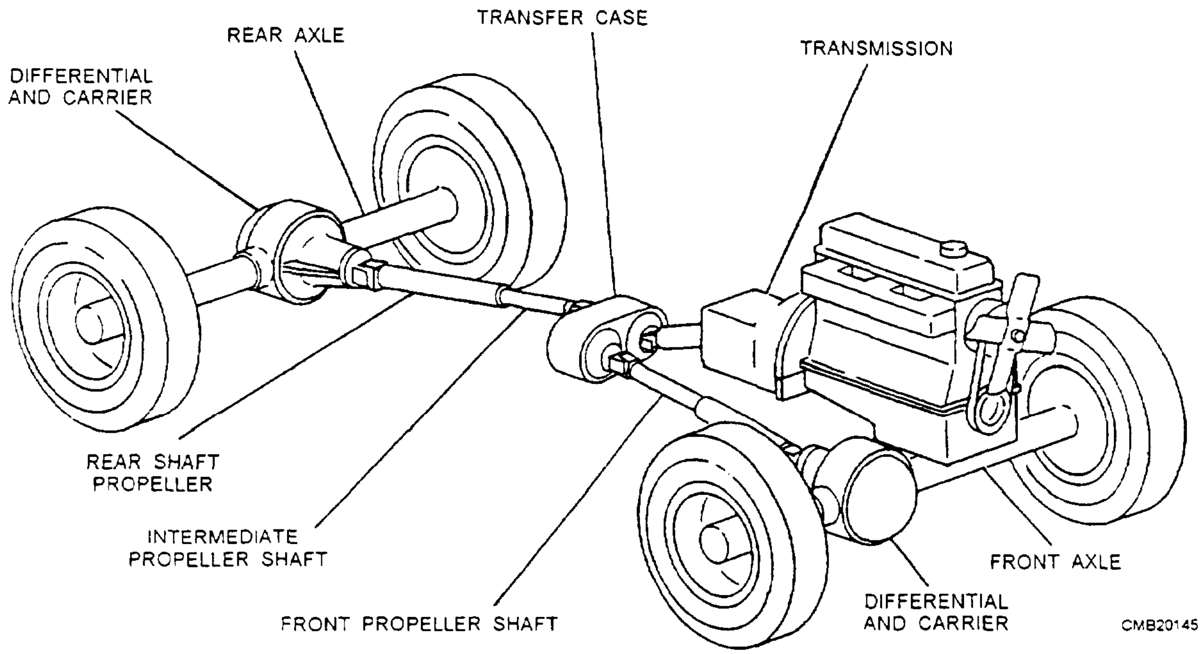


Figure 5-27.—Typical drive line arrangement with a transfer case.

Conventional transfer cases in heavier vehicles have two-speed positions and a de-clutching device for disconnecting the front-driving wheels. A cross section of a conventional two-speed transfer case is shown in figure 5-28. This type of transfer case is used for a six-wheel drive vehicle. Some light-duty vehicles use a chain to transmit torque to the front-driving axle (fig. 5-29).

The conventional transfer case provides a high and low final drive gear range in the same manner as an auxiliary transmission. In most cases, the shifting is accomplished through a sliding dog clutch, and shifting must be done while the vehicle is not moving. Typical operation of a conventional two-speed transfer case is as follows:

- **High Range** (fig. 5-30)—When driving the front and rear axles in the high range (1:1 gear ratio), the external teeth of the sliding gear

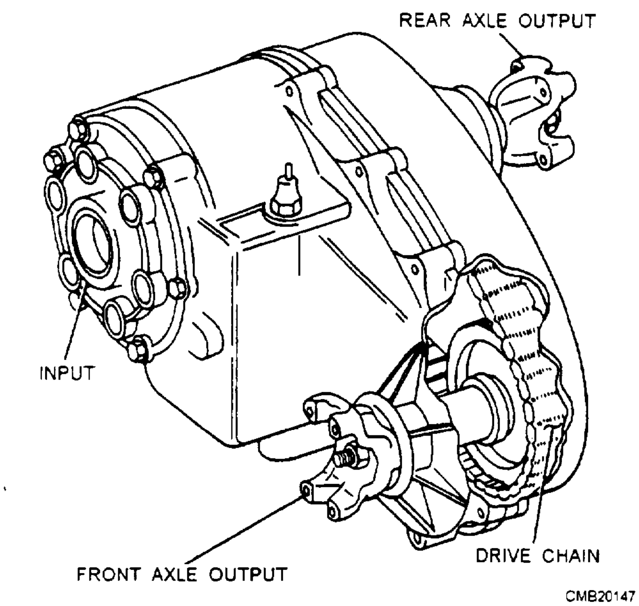
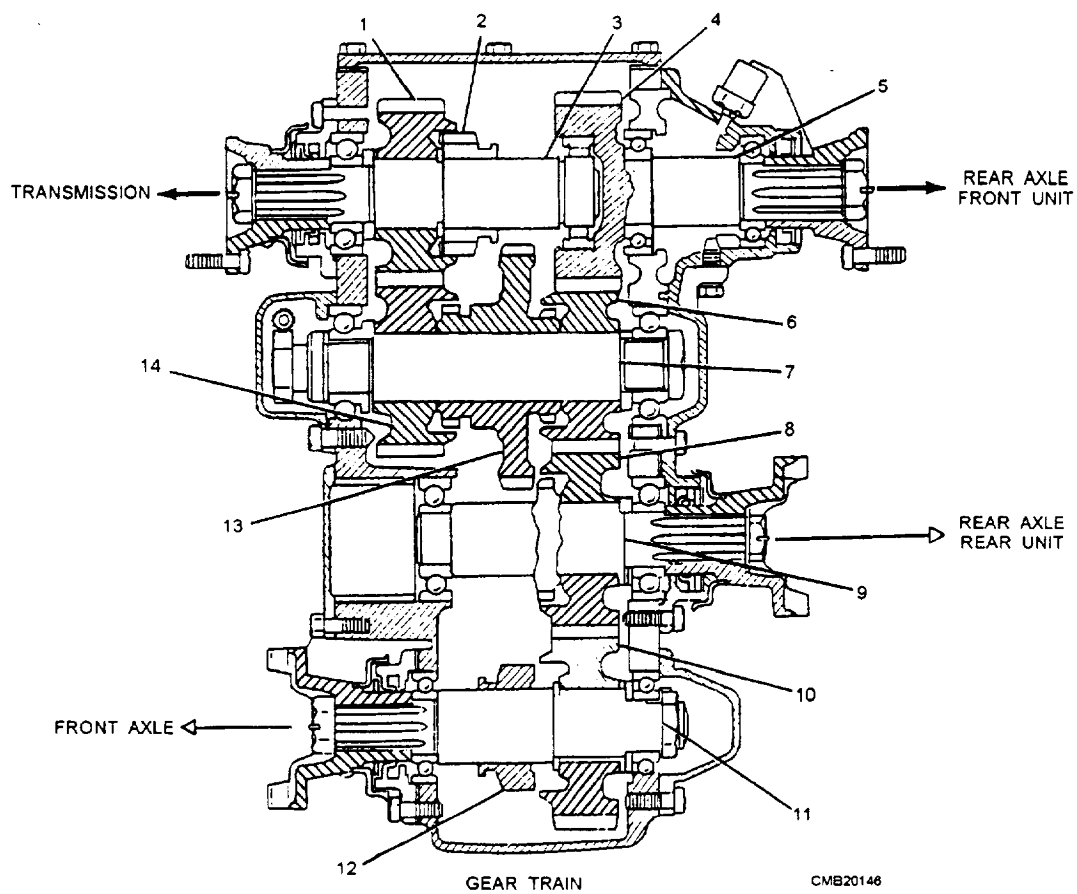


Figure 5-29.—Typical conventional transfer case using chain drive.



1. MAINSHAFT CONSTANT MESH GEAR
2. MAINSHAFT SLIDING GEAR
3. MAINSHAFT
4. REAR AXLE (REAR UNIT) DRIVE GEAR
5 REAR AXLE (REAR UNIT) DRIVE GEAR ASSEMBLY
6. IDLER SHAFT CONSTANT MESH GEAR
7. IDLER SHAFT
8. DRIVE SHAFT CONSTANT MESH GEAR
9. REAR AXLE (FRONT UNIT) DRIVE SHAFT
10. DRIVE SHAFT CONSTANT MESH GEAR
11. FRONT AXLE DRIVE SHAFT
12. DRIVE SHAFT SLIDING GEAR
13. IDLER SHAFT LOW SPEED GEAR
14. IDLER SHAFT CONSTANT MESH GEAR

Figure 5-28.—Cross-section of a typical conventional transfer case.

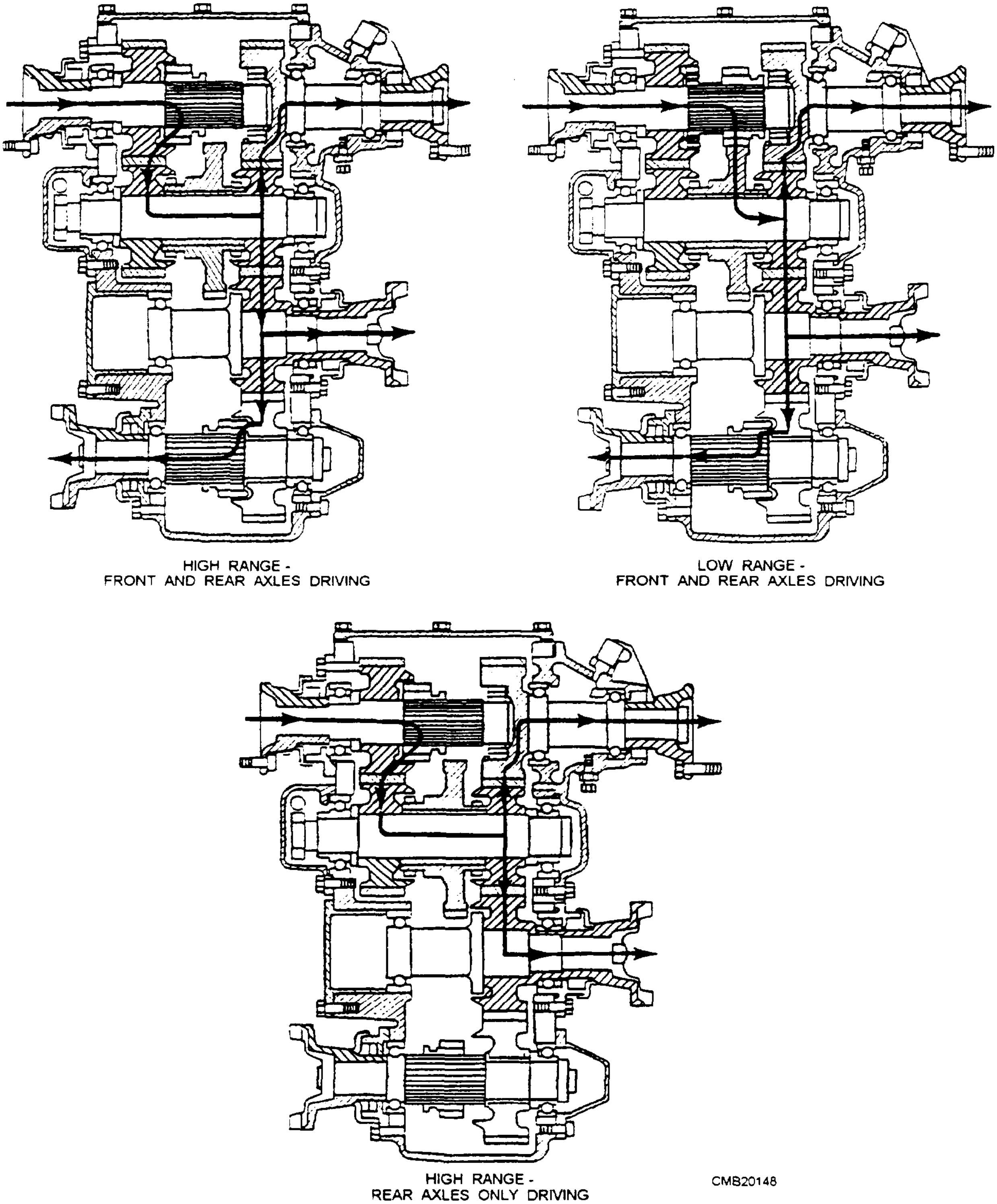


Figure 5-30.—Transfer case power flow.

(splined to the transmission main shaft) are in mesh with the internal teeth on the constant mesh gear, mounted on the transmission main shaft. Likewise, the external teeth of the front axle sliding gear are in mesh with the internal teeth of the constant mesh gear or the sliding clutches are engaged. Disengagement of the drive to the front axle is accomplished by shifting the sliding gear on the front axle main shaft out of mesh with the constant mesh gear, permitting the latter to roll free on the shaft or sliding the clutches out of mesh.

- **Low Range** (fig. 5-29)—When using the low range in the transfer case, the sliding gear on the transmission main shaft is disengaged from the constant mesh gear and engaged with the idler gear on the idler shaft. This design reduces the speed by having the sliding gear mesh with the larger idler gear. The shifting linkage on some vehicles is arranged so shifting into low range is possible only when the drive to the front axle is engaged. This design prevents the operator from applying maximum torque to the rear drive only, which can cause damage.

POSITIVE TRACTION TRANSFER CASE

The positive traction transfer case is very similar to the conventional transfer case—the basic difference being that a sprag unit has been substituted for the hand-operated sliding clutch on the front output shaft.

A sprag unit is a steel block shaped to act as a wedge in the complete assembly. In the sprag unit there are 42 sprags assembled into an outer race and held into place by two energizing springs (fig. 5-31). The springs fit into notches in the ends of the sprags and hold them in position. The outer race is the driven gear on the front output shaft. The inner race is on the front output shaft itself.

On these units, the transfer case is designed to drive the front axle slightly slower than the rear axle. During normal operation, when both front and rear wheels of the vehicle are turning at the same speed, the outer race of the sprag unit (in the driven gear) turns slower than the inner race (on the output shaft). This design prevents the sprags from wedging between the races. No lockup occurs and the front wheels turn freely; they are not driven (fig. 5-32). However, if the rear wheels should lose traction and begin to slip, they tend to turn faster than the front wheels; the outer race tends to turn faster than the inner race. When this happens, the sprags wedge or jam between the two races and the races turn as a unit to provide power to the front wheels (fig. 5-32).

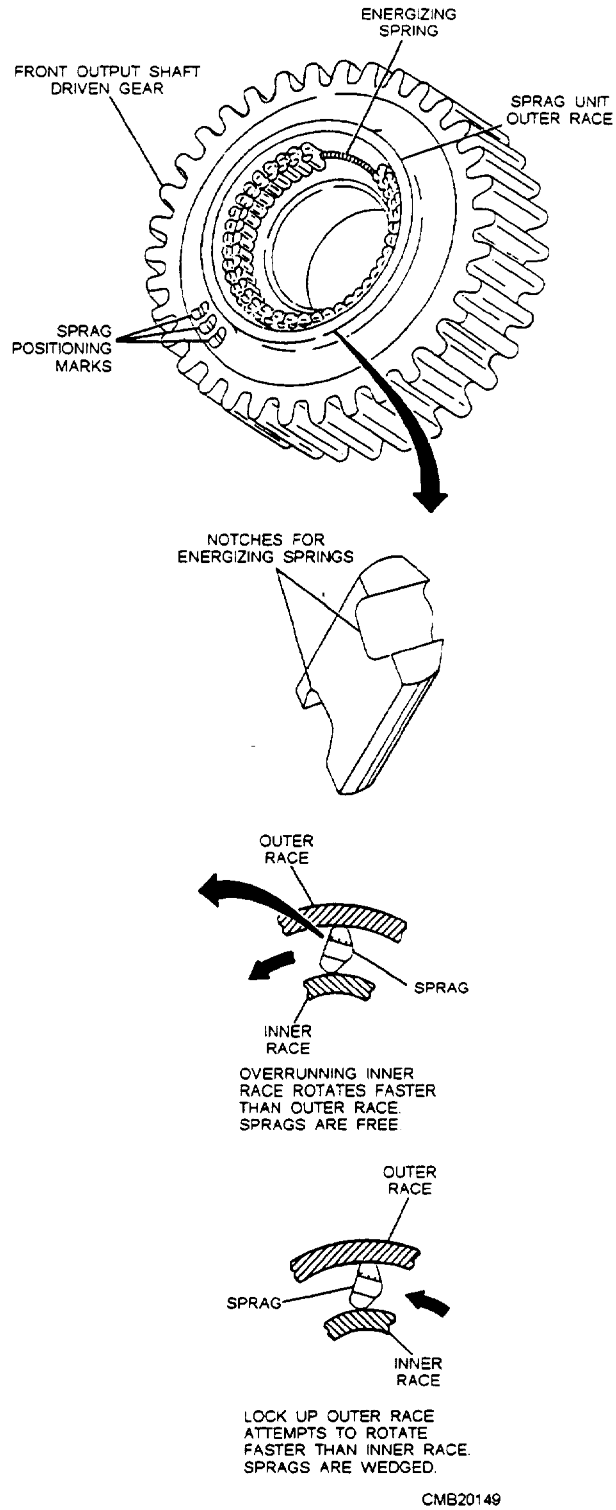


Figure 5-31.—Transfer case sprag unit.

TRANSFER CASE MAINTENANCE AND SERVICE

The fluid level in a transfer case should be checked at recommended intervals. To check the lubricant level, remove the transfer case fill plug, which is normally located on the side or rear of the case. The lubricant should be almost even with the fill hole. If required, add the recommended type and amount.

The first indication of trouble within a transfer case, as with other components of the power train, is usually noisy operation. If an operator reports trouble, make a visual inspection before removing the unit

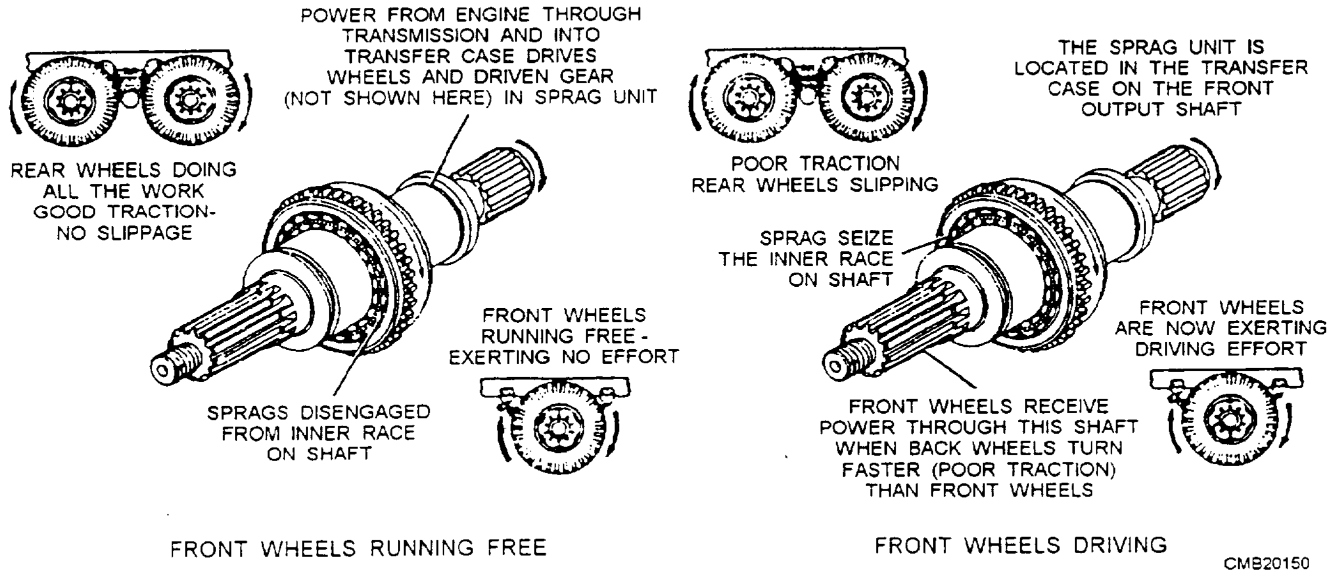


Figure 5-32.—Positive traction transfer case operation.

from the vehicle. Check for such things as oil level, oil leakage, and water in the oil.

Make sure the shift lever linkages are not bent or improperly, lubricated. This will make it hard to shift or, in some cases, impossible to shift. Make sure other possible troubles, such as clutch slippage, damaged drive shaft, and damaged axles, have been eliminated.

Worn or broken gears, worn bearings, and excessive end play in the shafts can cause noisy operation. When transfer case service is required, follow the procedures outlined in the service manual. It will give directions for repairing the particular make and model.

REVIEW 4 QUESTION

Q1. What is the gear ratio when a conventional transfer case is in high range?

Q2. What component in a positive traction transfer case provides power to the front wheels when the rear wheel begins to slip?

POWER TAKEOFFS

Learning Objective: Explain the operation of a power takeoff unit.

A power takeoff (PTO) is an attachment for connecting the engine to power-driven auxiliary equipment. It is attached to the transmission, auxiliary transmission. or transfer case. A power takeoff installed at the left side of a transmission is shown in figure 5-33. It is used to drive a winch at the front of a truck through a universal joint and drive shaft.

The simplest type of power takeoff is the single-speed, single-gear shown in figure 5-34. This unit may be bolted to an opening provided in the side of a transmission, as shown in figure 5-35.

Shims or spacers are often used to ensure proper contact is maintained between the teeth of the two meshing units. The sliding gear of the PTO can then mesh with, and be driven by, the countershaft gear of the transmission or the auxiliary transmission when engaged by the operator. The operator, by the use of a control lever, can move the gear in and out of mesh with the transmission gear. A spring-loaded ball (poppet) holds the shifter shaft in position.

On some vehicles you will find PTOs with gear arrangements that give you two speeds forward and one in reverse. Several forward speeds and a reverse gear are usually provided in a PTO unit used to operate a winch or hoist. Operation of this type of PTO is similar to that of the single-speed unit.

Faulty operation of a PTO is caused by damaged or broken linkage. To prevent this, exercise care when shifting. Trying to engage the unit with the transmission gears turning can damage the teeth, and rapid clutch engagement can break the housing. Rapid shifting may bend or damage the linkage. Forcing the control lever can bend or break the linkage.

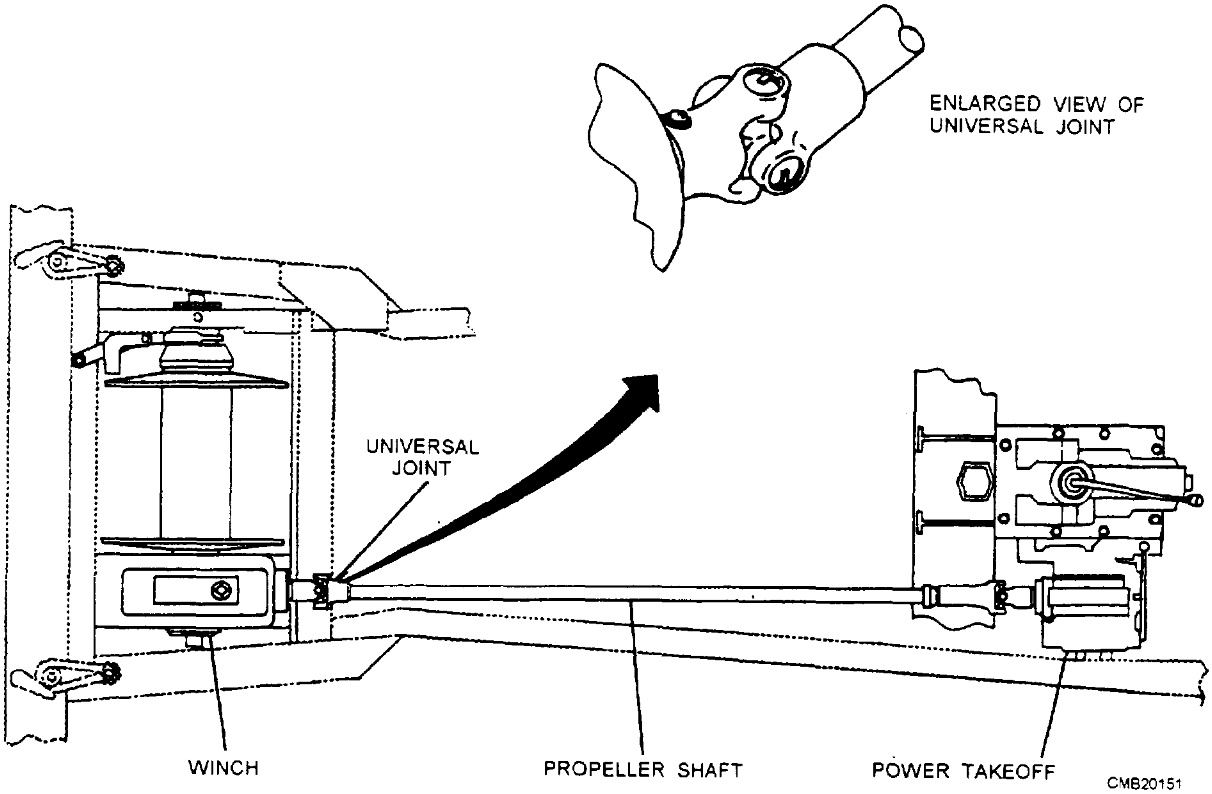


Figure 5-33.—Power takeoff and winch installation.

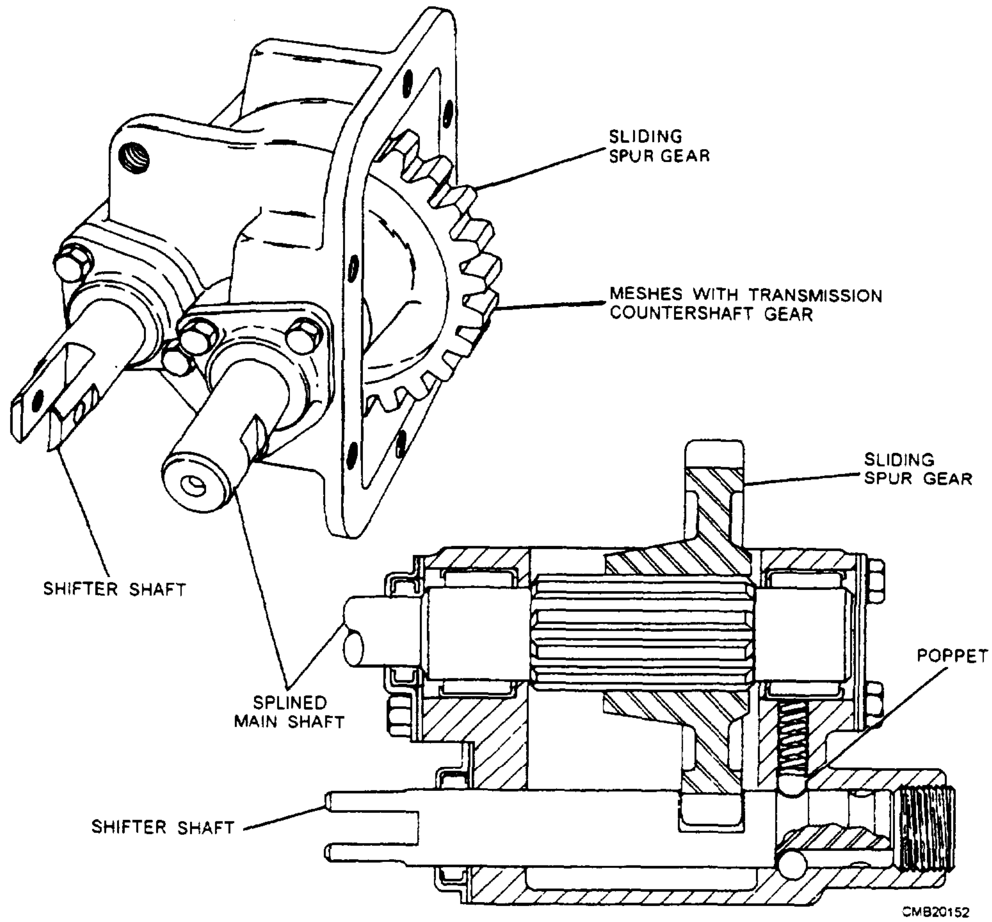


Figure 5-34.—Single-speed, single-gear power takeoff.

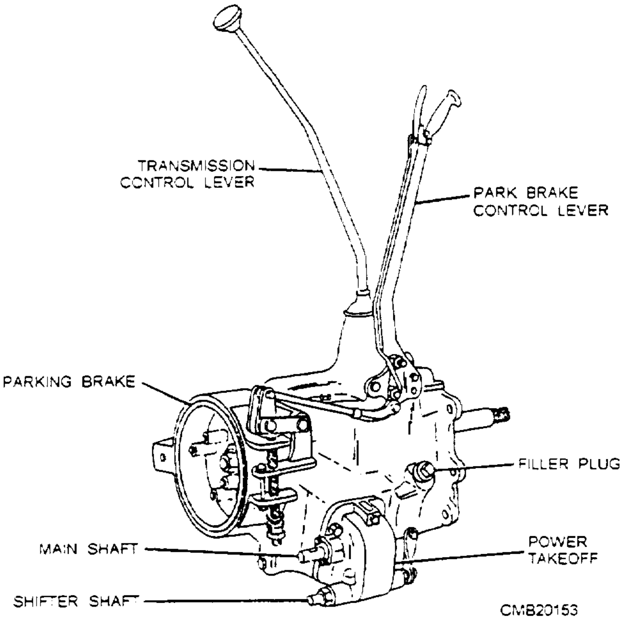


Figure 5-35.—Single-speed, single-gear power takeoff installation.

Adjustment of the linkage to compensate for wear and lubrication is normally all the maintenance required for the PTO unit. The gears and bearings are lubricated from the transmission sump.

If the PTO is to be removed for repairs. disconnect the drive shaft and shift linkage and drain the transmission. Once the transmission is completely drained, remove the bolts that secure the unit to the transmission. DO NOT misplace or lose any shims or spacers that are between the two housings. Once the unit is removed from the vehicle, the inspection and repair procedures are the same as for a transmission. When reinstalling or replacing the PTO, carefully follow the manufacturer's procedures on the installation shims or spacers to prevent damage or unit failure.

REVIEW 5 QUESTIONS

Q1. What is the simplest type of power takeoff (PTO)?

REVIEW 1 ANSWERS

Q1. *To send turning power from the transmission to the rear axle assembly, flex and allow up and down movement of the rear axle assembly, provide a sliding action to adjust for changes in drive line length, andprovide smooth power transfer*

Q2. *True*

Q3. *To maintain alignment of two or more drive shafts when connected in tandem*

Q4. *Worn universal joint*

Q5. *Wiggle and rotate the universal joint back and forth*

Q6. *True*

REVIEW 2 ANSWERS

Q1. *Differential*

Q2. *True*

Q3. *Pinion gear, ring gear*

Q4. *True*

Q5. *Limited slip differential*

Q6. *True*

REVIEW 3 ANSWERS

Q1. *Breather vent*

Q2. *Full-floating axle*

Q3. *Rzeppa and Bendix- Weiss*

Q4. *Constant whirring or humming sound*

Q5. *Slide-hammer puller*

REVIEW 4 ANSWERS

Q1. *1:1*

Q2. *Sprag unit*

REVIEW 5 ANSWERS

Q1. *Single-speed single-gear*